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United States
Department of
Agriculture



Forest Service

Forest Pest
Management

Davis, CA

Deposition of Bacillus thuringiensis into Gambel oak canopies



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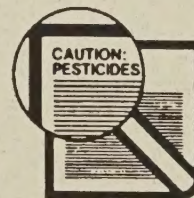
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FOREWORD

FPM 92-9
July 1992

**Deposition of Bacillus
thuringiensis into
Gambel oak canopies**

REGISTERED
OCT 12 2011

BY:

Prepared by

Bruce Grim
James Rafferty
Gary Sutton
Tom Clarke

U.S. Army Dugway
Proving Ground
Utah 84022

In cooperation with

USDA Forest Service
Forest Pest Management
2121C Second Street
Davis, CA 95616

(916) 758-4600

FOREWORD

This project was accomplished under RDTE Project 1M4657104049, Joint Chemical/Biological (CB) Contact Point and Test (Project DO49), which is managed and executed by the Joint Operational Test and Information Directorate (JOD), U.S. Army Dugway Proving Ground, Dugway, Utah.

This field test was a cooperative effort between the USDA Forest Service and the U.S. Army under a supplemental agreement to the master memorandum of understanding between the agencies for cooperation with respect to food, agriculture and other research of mutual interest.

The canopy penetration test was designed by Mr. Grim (JOD-A-DPG) and Mr. Rafferty (MT-M-DPG) and was conducted by Lockheed Corporation under contract to the Materiel Test Directorate, Dugway Proving Ground. Life Sciences Division (MT-L-DPG) machine counted the card samples which were analyzed by Mr. Rafferty. Mr. Sutton of the Test Management Division (MT-TM-DPG) was the project officer in charge of the test and provided much of the data reduction. Mr. John Barry of the USDA Forest Service, Forest Pest Management provided many valuable suggestions for the test design and coordinated much of the effort with the other Forest Service participants including having the the deposition cards hand counted. The USFS Missoula Technical Development Center provided valuable meteorological support as did the Atmospheric Sciences Division (ASD) Dugway Meteorological Team. Mr. John Anhold of the USDA Forest Service, Intermountain Region Offices was in charge of the overall aerial spray effort and fully supported this piggyback spray penetration study. Mr. Mark Quilter, Utah Department of Agriculture provided valuable services in coordinating among various organizations.

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EXECUTIVE SUMMARY

A series of canopy penetration field trials were conducted in Gambel Oak canopies located in the Wasatch Mountains east of Salt Lake City, Utah in conjunction with aerial spraying to control a Gypsy Moth infestation during May-June of 1990 and 1991. These trials were a cooperative effort between the USDA Forest Service and U.S. Army Dugway Proving Ground for the purpose of evaluating a new method of determining input parameters for the canopy penetration module of the FSCBG aerial spray model which was developed jointly by the two organizations. A photoelectric measuring instrument was used to quantitatively measure the canopy foliage density, a parameter which was formerly estimated by subjective means. Spray droplet deposition was measured at above, mid, and below canopy sampling positions using Kromecote sampling cards. An average of one third ($1/3$) of the deposition measured above the canopy penetrated to the below canopy sampling positions. A follow-on report will examine data/model comparisons of the canopy penetration module of FSCBG using the photoelectric canopy density measurements.

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SECTION 1. INTRODUCTION

1.1 BACKGROUND

The USDA Forest Service (FS) and U.S. Army Dugway Proving Ground (DPG) over the past 15 years have maintained a cooperative program to develop an aerial spray dispersion model which includes a canopy penetration module. The canopy penetration module requires that the canopy density be defined by a probability of penetration, average tree profile, and number of trees per acre. Estimates of these parameters are somewhat subjective, especially the probability of penetration. A photoelectric measuring instrument has recently (1990) been marketed by the LI-COR Corp. (4421 Superior ST., P.O. Box 4425, Lincoln, Neb. 68504) which has the capability to measure Leaf Area Index (LAI) in a plant canopy. The LI-COR plant canopy analyzer (LAI-2000) has the potential to eliminate the subjectivity in estimating the parameters which are used in the canopy penetration portion of the FSCBG (Ref. 1) aerial spray model. FSCBG has been modified by Continuum Dynamics, Inc. (Ref. 2) to take LAI-2000 measurements directly as a measure of canopy density.

The FS, Intermountain Region (R-4) and the Utah Department of Agriculture have been conducting a spray program to eradicate the gypsy moth which have infested Gambel oak stands and urban forests along the Wasatch Front of Utah. In the spring of 1990 and 1991 the FS and DPG cooperated in a series of field experiments to measure the penetration of *Bacillus thuringiensis* (Bt) insecticide spray into the Gambel oak stands. In the 1991 trial series the LAI-2000 plant canopy analyzer was used to collect canopy density information for input to FSCBG. A comparison of model predictions with the actual canopy penetration sampling data will be made in a follow-on report.

1.2 OBJECTIVES

The objective of the field trial series was to obtain a measure of the amount of aerial spray material released above the canopy which penetrates through the canopy to the ground. This provides the FS with a measure of the effectiveness of the spray mix to coat the leaf surface which the gypsy moth larvae consume.

1.3 COOPERATORS

USDA Forest Service, Intermountain Region, Ogden, UT

USDA Forest Service, Forest Pest Management, Washington Office, Davis, CA

USDA Forest Service, Missoula Technical Development Center (MTDC), Missoula, MT

U.S. Army Dugway Proving Ground, Dugway, UT

1.4 DESCRIPTION OF FIELD TRIALS

1.4.1 1990 Field Trials

The 1990 spray deposition study was conducted at three of ten spray blocks located along the Wasatch Front. The three blocks were located: (a) on the south side of Parley's Canyon about a mile west of Lamb's Canyon, (b) on the north west ridge of Mt Olympus just above the highest homes, and (c) at the mouth of Rock Canyon on the south side of Provo Canyon. At each of these sites, sampling was done during each of three spray applications.

A straight sampling line 100 m in length was constructed at each of the three test sites. The line was oriented along the fall line (i.e., perpendicular to the elevation contours) so that it would be perpendicular to the flight path of the application aircraft. Along this line, 41 numbered sampling positions at 2.5-m intervals were established (Figure 1). The sampling positions were numbered in ascending order with position #1 at the lowest elevation. At each position, a kromekote™ card (11.0 cm x 16.8 cm) was placed at ground level. Also, vertical sampling poles were erected at 5-m intervals (odd position numbers) to provide mid-canopy and above-canopy sampling platforms at 21 locations.

The vertical sampling platform consisted of two 10-ft (3.05-m) metal electrical conduits with diameters of 1 in (2.54 cm). The poles were lashed together using two screw-type hose clamps on a section that overlaps 1 ft (0.305 m) as shown in Figure 2. The resulting 19 ft (5.76 m) pole was supported by guy wires attached to available trees or stakes. At mid-canopy one-half of a standard deposition card was mounted on a platform that extended 1 ft at right angles from the top of the lower pole. The platform was oriented upslope of the pole (upwind for the assumed drainage winds). At the top of the upper pole, one-quarter of a standard deposition card was mounted on a platform. This arrangement provided sampling at the ground, near mid-canopy, (10 ft or 3.05 m), and above the canopy (19 ft or 5.79 m). Most of the trees in the sampling locations did not exceed 19 ft in height; however, if the trees in the vicinity of a sampling pole exceeded 19 ft, an extra 5 ft extension of conduit was lashed to the upper pole with a 6 in overlap to put the deposition card above canopy sampling height at 23.5 ft (7.16 m).

Leaf emergence was at different stages during each application time as illustrated in Figure 3. At each sampling area and at the time of each application, photographs of the canopy were taken at sampling locations #10, #20, and #30. The photographs were taken looking upline (uphill) at elevation angles of 15, 30, 45, 60, 75, and 90 degrees from the horizontal. The photographs were taken at a time of day that would provide maximum contrast between the foliage in the foreground and the sky in the background.

The forest at each test site was characterized by surveying plots at each sampling location where the photographs were taken to estimate stems per acre, trunk diameter, crown width and height, and tree height. This information is summarized in Figure 4.

The Test and Evaluation Command (TECOM), Meteorological Team at DPG provided the following services at each block for each of the 9 days when sampling occurred:

1. Recorded surface observations for a period starting one hour before the block was sprayed to one hour after spraying; observations included air temperature, relative humidity, barometric pressure, cloud cover and height, visibility, present weather, and ground conditions.
2. Recorded wind observations from a 2-m mast for the same period and location as the surface observations. The 2-m mast is shown in Figure 5.
3. Recorded Pibal wind measurements to 2000 m above ground level immediately after the spray aircraft left the area.
4. Provided two helium filled balloons to be tethered at a height 2 m above the canopy at either end of the sampling line for pilot identification of the sampling area.

1.42 1991 Field Trials

The 1991 spray deposition study was located in Parley's canyon south of I-80 freeway and east of the Mountain Dell exit in a fairly uniform stand of Gambel oak (Figure 6). Sampling was done on the three spray application days, as described for the 1990 field trials.

Two 102.5 m long sampling lines were constructed along a line roughly perpendicular to the contour lines and thus perpendicular to the helicopter spray paths. There were 42 numbered sampling positions along each of the two sampling lines. The sampling lines were numbered in ascending order with positions #1 and #43 at the lowest elevation. At each position, a deposition card was placed at ground level. Also, vertical sampling poles were erected at 5-m intervals (odd numbered positions) to provide mid-canopy and above-canopy sampling platforms at 42 locations. See Figure 7.

The vertical sampling platform consisted of two 10-ft (3.05-m) metal electrical conduits with diameters of 1 in (2.54 cm) in the same configuration as previously described for the 1990 trials (Figure 2). In 1991 a full size deposition card (11.0 cm X 16.8 cm) was used at all sampling positions.

Leaf emergence was at different stages at each application time. The LAI-2000 Plant Canopy Analyzer was utilized to monitor the relative amount of light penetrating the canopy at each application. Ten (10) readings were taken at preselected locations between the two sampling lines. In order to minimize problems with direct sunlight these readings were taken at dawn before the sun emerged over the apparent horizon.

Meteorological measurements were taken by the TECOM Met Team from DPG and a single 5-m telescoping meteorological mast was erected in a nearby clearing by the Forest Service, Missoula, Montana and is shown in Figure 8.

The following meteorological data were taken during the trials:

1. Surface observations for a period of one hour before the block was sprayed to one hour after spraying; the observations included air temperature, relative humidity, barometric pressure, cloud cover and height, visibility, present weather, and ground conditions.
2. Recorded wind observations from a 2-m mast for the same period and location as the surface observations.
3. Wind speed and direction, temperature, and relative humidity from 5-m mast.

1.4.3 Aerial Spray Application

Aerial application of undiluted Bt (Foray 48B undiluted) in all trials at the rate of 0.5 gal/acre was sprayed by helicopter flying at a nominal 50 ft above the canopy with an approximate airspeed of 70 knots and a lane spacing (swath width) of approximately 100 ft. Each helicopter was equipped with four Beecomist 360A atomizers. Atomizer positions on the boom were estimated by AGDISP3 model simulations and final positioning was adjusted by observing the spray pattern produced on sample cards at ground level at Salt Lake Airport No. 2 prior to the actual spray application. Final atomizer positions along the spray boom are given in Table 1.

SECTION 2. RESULTS AND CONCLUSIONS

2.1 TRIAL RESULTS FOR 1990

Leaf emergence for a typical Gambel Oak tree at the Parley's Canyon site at the time of each spray application is illustrated in Figure 3 and the typical tree envelopes for each site are shown in Figure 4. These profiles are subjective in nature, though they are based on photographs and visual estimates made on site. Stems per acre estimates were based on average measurements of tree spacing at each vertical sampling position. Due to the time consuming nature of obtaining these measurements, use of a measuring device such as the LI-COR LAI-2000 plant canopy analyzer appears to be imperative for obtaining input parameter values for FSCBG. LAI-2000 measurements were taken at each of these sites in 1991 with full leaf emergence and are presented in Table 3. Analysis of the numerous photographs taken for the purpose of obtaining FSCBG inputs was initiated after the trials; however, when the analysts became aware of the LAI-2000 plant canopy analyzer, further analysis of the photographs was halted.

The major objective of the test to measure the amount of spray penetrating the foliage was satisfied. Data as shown in Figures 9 through 17 illustrate the deposition obtained at the three levels (above, mid, and below canopy) as a function of line position for the 1990 trials. The peaks and valleys are a result of helicopter position and spray drift due to wind, while variations in canopy density show up as scatter. On the average the above canopy depositions are greater than mid and below canopy depositions as one would anticipate, and approximately one third (1/3) of the spray material reached the ground.

2.2 TRIAL RESULTS FOR 1991

Figures 18-23 (hand counts) and Figures 24-29 (machine counts) depict the deposition measured at above, mid, and below canopy levels for each sampling position for the Parley's canyon site. As was the case in 1990, approximately one third (1/3) of the spray measured above the canopy was recovered at ground level below the canopy. The Canopy penetration ratios for both the 1990 and 1991 trials are shown in Table 4. Statistical comparisons of the deposition data are presented in Appendix F and the following results were noted:

1. No significant differences were noted between trials at above, mid, or below canopy levels.
(Note: There was a significant difference between vertical levels, not trials.)
This indicates that the effect of leaf emergence as a function of spray date was indistinguishable in this series of trials.
2. No significant differences were noted between the two parallel sampling lines with either the hand counted or machine counted card samples.
3. It is recommended that trial #3 HAND COUNTS not be used for field data to FSCBG model comparisons due to difficulties experienced by the card reader (mid-canopy cards were not read) in seeing the droplets.

2.3 TRIAL RESULTS FOR COLLECTION EFFICIENCY OF DIFFERENT SIZED SAMPLE CARDS

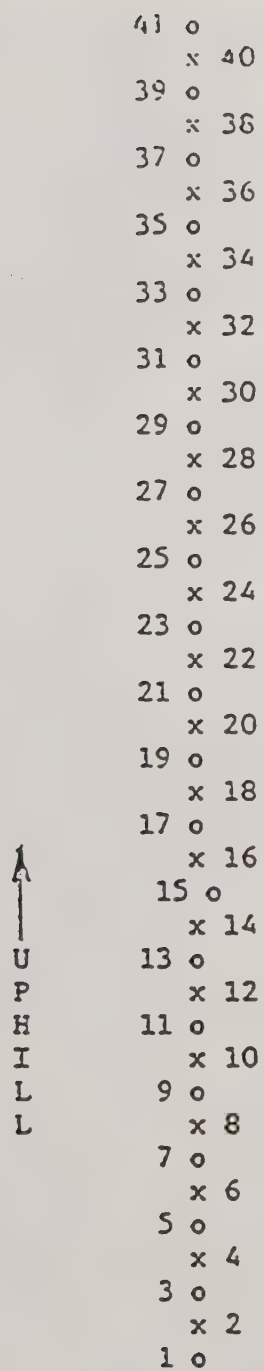
The use of 3 different card sizes at the different sampling levels during the 1990 trials raised some concern on the part of analysts as to whether card size would affect collection efficiency. A small experiment was set up during each trial in 1991 in an open area which was within the Parley's Canyon spray block. An array of 24 cards of each size was arranged in an area of approximately 3 meters square. Statistical test results are given in appendix E. A two-way factorial analysis on the response variable mg/m^2 with the main effects tested being application number and size of card was performed. Not unexpectedly, card density was significantly different from application to application. Card size unexpectedly showed a significant difference; however, inspection of the interaction term (size) suggests that a fluctuation in application #2 may be responsible. To further test these results a new experiment will be conducted during the spring of 1992 Gypsy Moth spray applications.

2.4 CONCLUSIONS

The average canopy penetration values obtained from these trials (approx. 1/3 penetration to the ground) reflect the lowest penetration one might expect in Gambel oak. Gambel oak in the western United States does not generally grow in uniform stands covering many acres, rather it is clumpy by nature and rarely exceeds 20 ft in height. The plots chosen in these studies were as uniform as could be found over the short distance of 100 meters which constituted the sampling lines.

2.5 RECOMMENDATIONS

1. The use of a second parallel sampling line as was done in the 1991 trials proved to be superfluous and is not recommended for future tests.
2. It is recommended that collection cards all be of the same size to avoid confusion of the data by possible differences in collection efficiency. Data from the 1991 card sizing test were statistically inconclusive on this point.
3. Use hand counted density data to compare with FSCBG predictions.



Ground Sample Interval = 2.5 meters
Pole Sample Interval = 5.0 meters

o = pole sample + ground sample
x = ground sample only

Figure 1. Sampling grid diagram for 1990 canopy penetration trials.



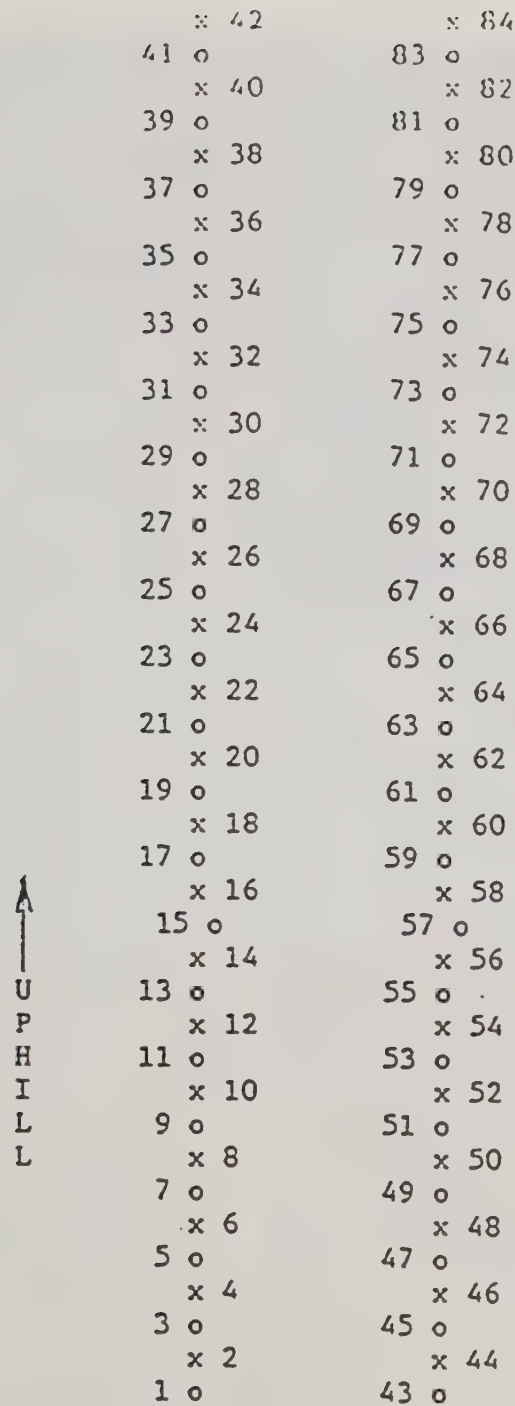
Figure 2. Workers installing sampling poles in Gambel Oak forest.



Figure 5. 2-meter meteorological sampling tower.



Figure 10. Parley's Canyon site of the 1991 canopy penetration study.



Ground Sample Interval = 2.5 meters
Pole Sample Interval = 5.0 meters

o = pole sample + ground sample
x = ground sample only

Figure 7. Sampling grid diagram for 1991 canopy penetration trials



Figure 8. 5-meter meteorological sampling tower.

1990 HELICOPTER NOZZLE POSITIONS

Aircraft Type	Rotor to Boom Distance (m)	Distance to Nozzles (m)			
		Left Outboard	Left Inboard	Right Inboard	Right Outboard
Hiller 12E		3.84	1.68	1.68	3.84
Bell 212 (2 ships)		3.84	1.73	1.75	3.84

1991 HELICOPTER NOZZLE POSITIONS

Aircraft Type	Rotor to Boom Distance (m)	Distance to Nozzles (m)			
		Left Outboard	Left Inboard	Right Inboard	Right Outboard
Hughes 500	1.9	3.01	1.65	1.75	3.09
Bell 206 #N16726	3.2	4.02	1.99	1.80	3.98
Bell 206 #N59553	3.2	4.00	1.86	1.77	3.92

HELICOPTER USAGE CHART

SITE	HELICOPTER
PARLEY'S 1990	HILLER
OLYMPUS 1990	HILLER
PROVO 1990	BELL 212 (2 SHIPS)
PARLEY'S 1991	HUGHES 500

Table 1. Helicopter nozzle positions and usage chart for 1990-1991 aerial spraying.

UTAH GYPSY MOTH 1990

Lamb's Canyon Application #1

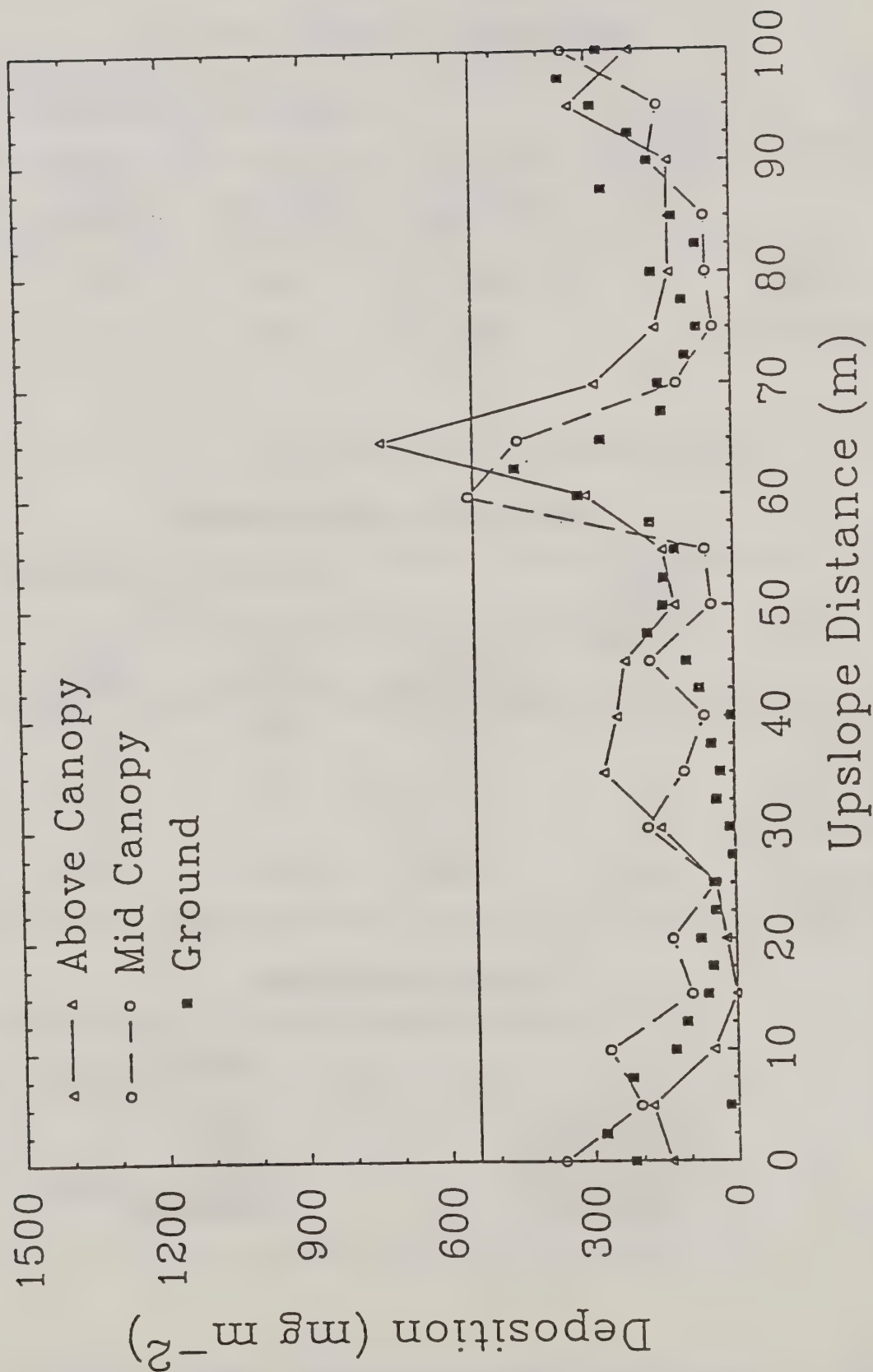


Figure 9. Deposition density vs sampler position for 1990 Parley's application #1.

UTAH GYPSY MOTH 1990

Lamb's Canyon Application #2

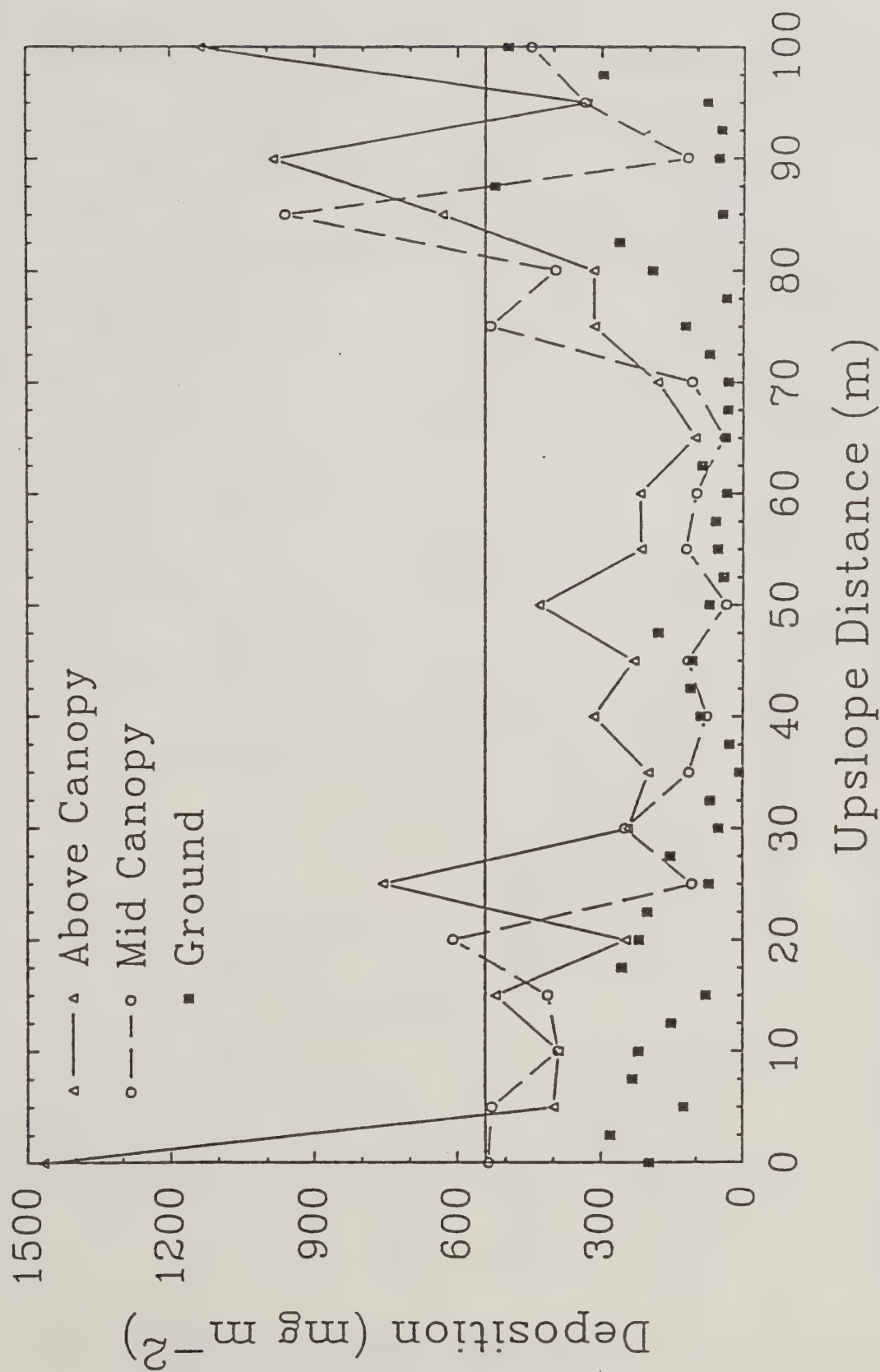


Figure 10. Deposition density vs sampler position for 1990 Parley's application #2.

UTAH GYPSY MOTH 1990

Lamb's Canyon Application #3

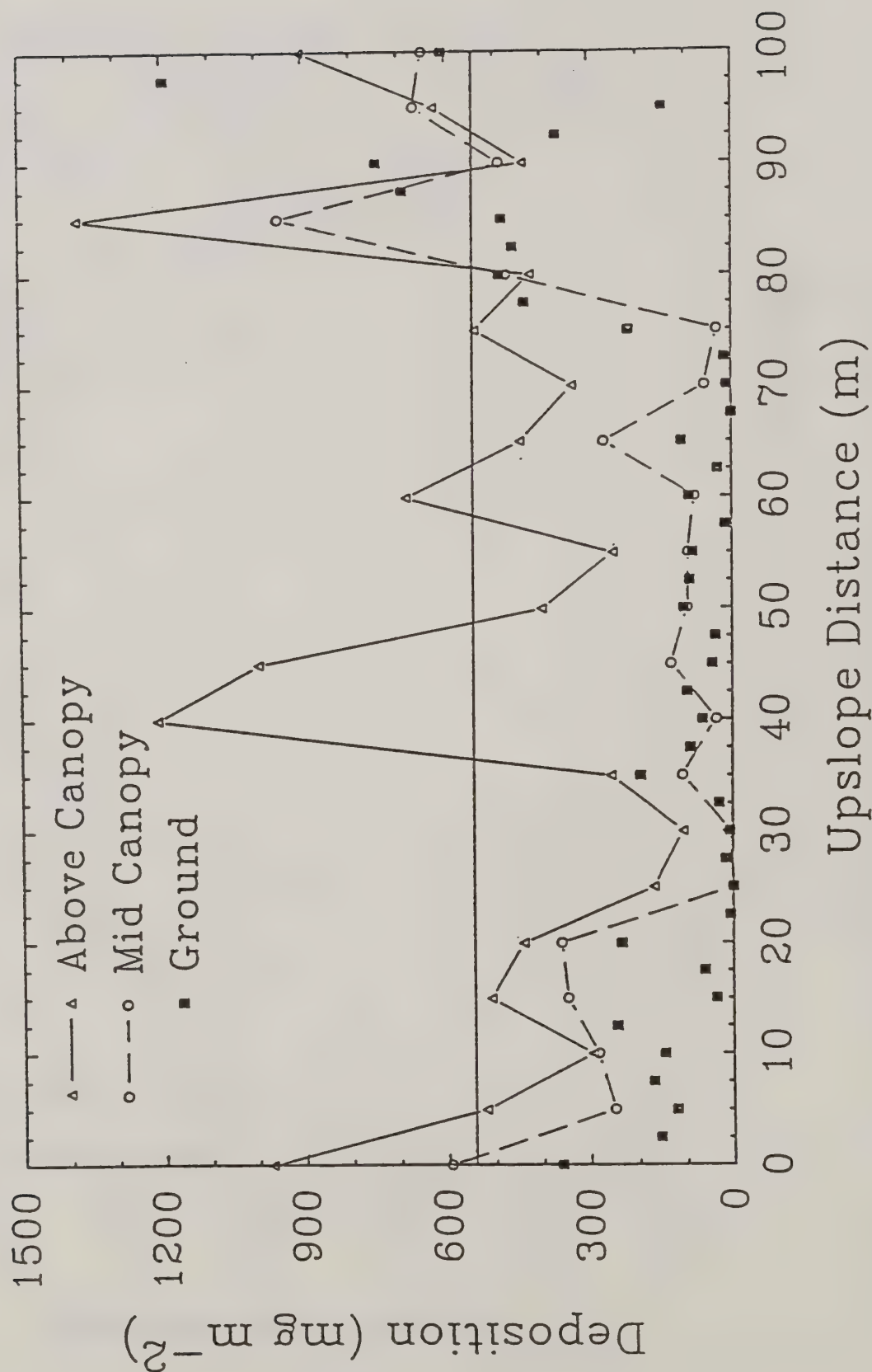


Figure 11. Deposition density vs sampler position for 1990 Parley's application #3.

UTAH GYPSY MOTH 1990

Olympus Cove Application #1

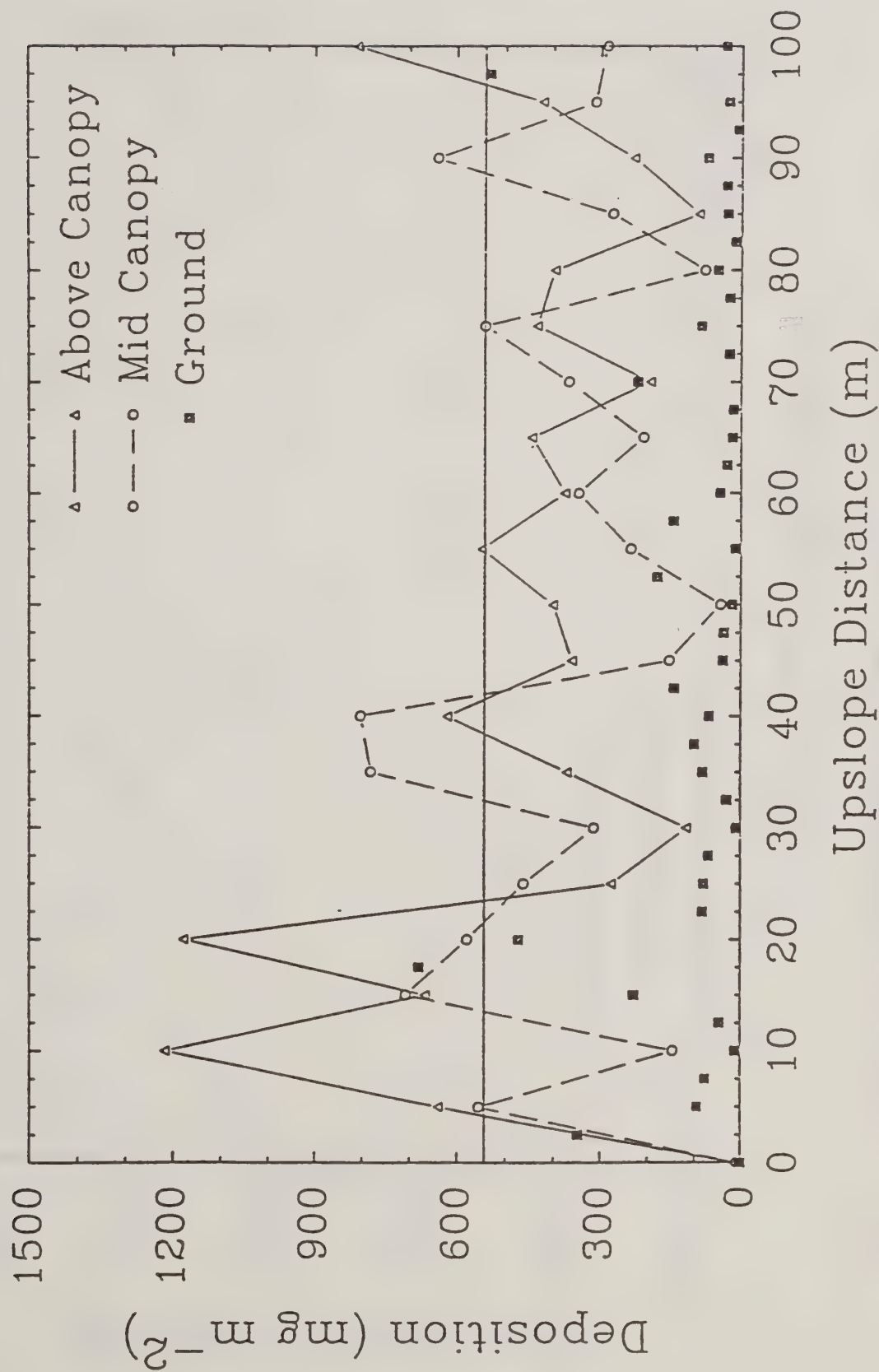


Figure 12. Deposition density vs sampler position for 1990 Olympus application #1.

UTAH GYPSY MOTH 1990

Olympus Cove Application #2

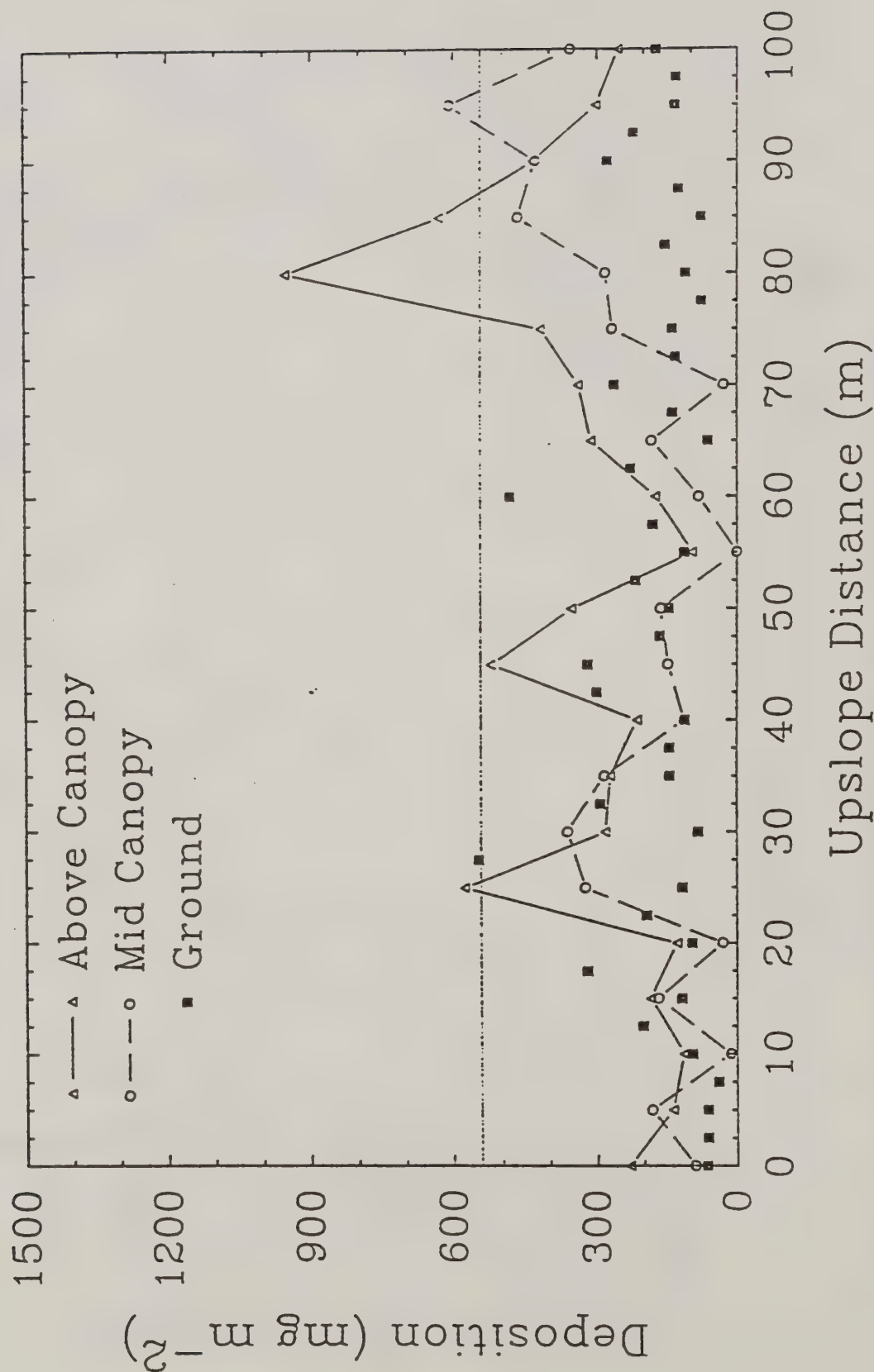


Figure 13. Deposition density vs sampler position for 1990 Olympus application #2.

UTAH GYPSY MOTH 1990

Olympus Cove Application #3

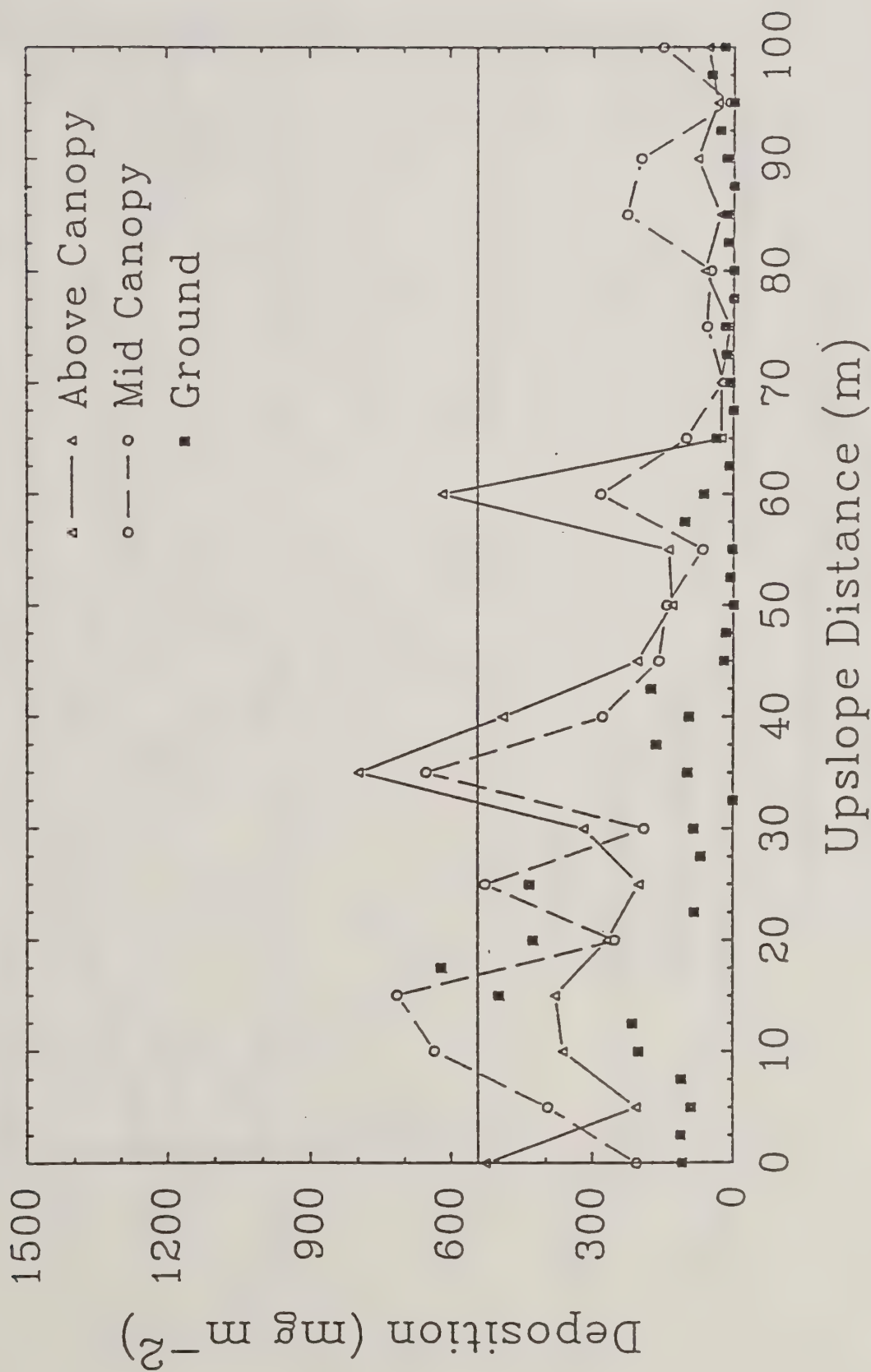


Figure 14. Deposition density vs sampler position for 1990 Olympus application #3.

UTAH GYPSY MOTH 1990

Provo Canyon Application #1

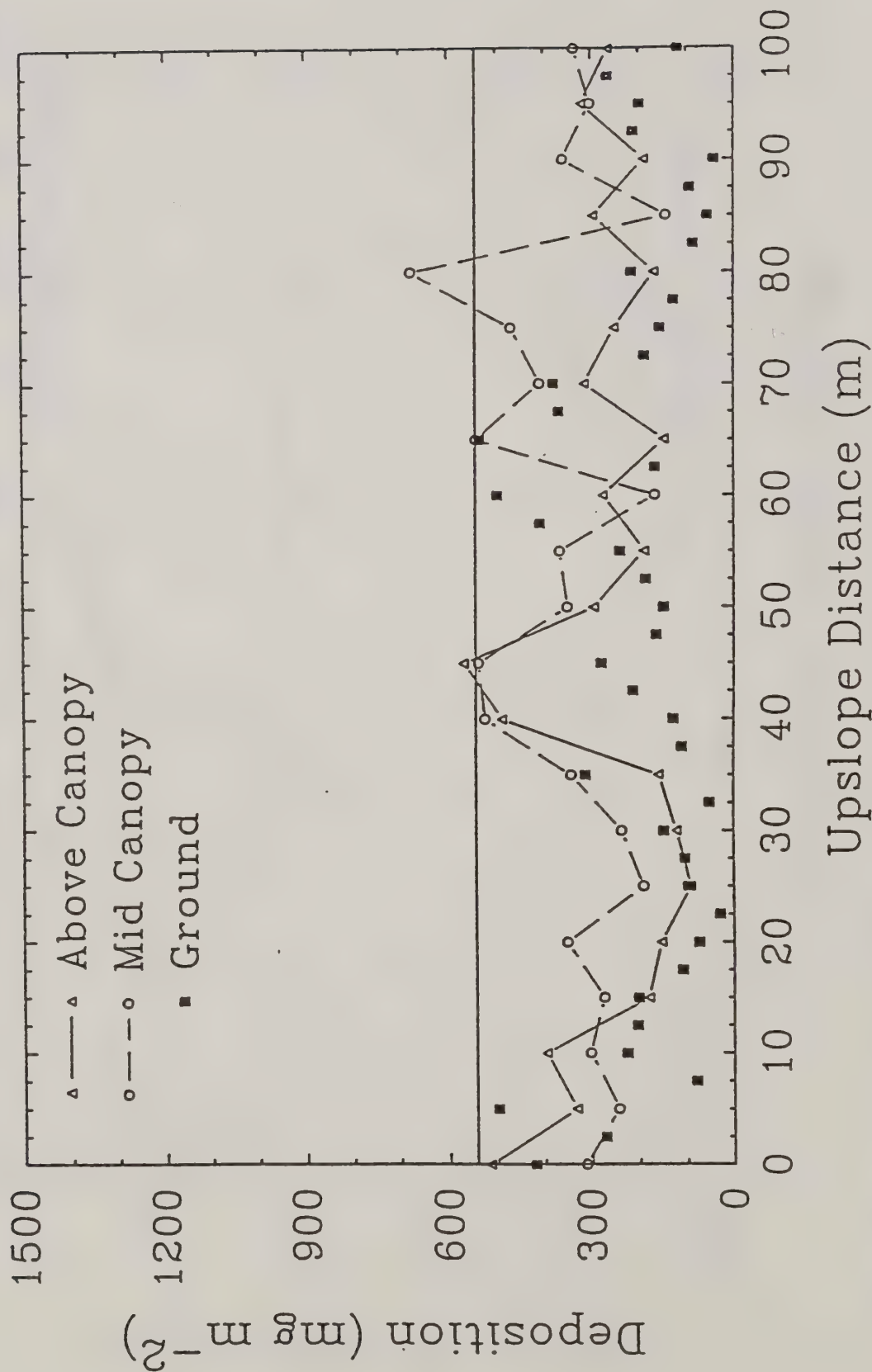


Figure 15. Deposition density vs sampler position for 1990 Provo application #1.

UTAH GYPSY MOTH 1990

Provo Canyon Application #2

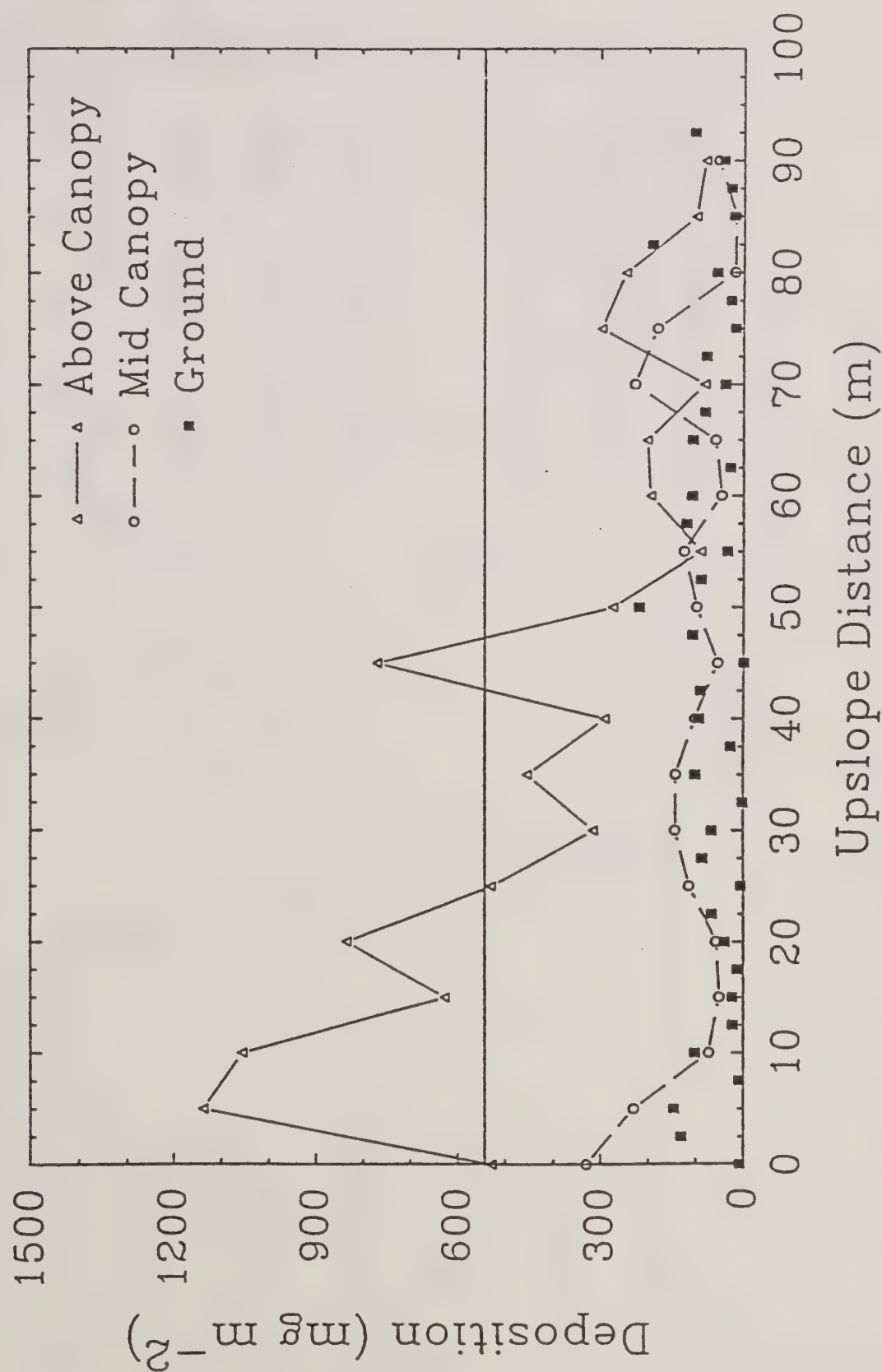


Figure 16. Deposition density vs sampler position for 1990 Provo application #2.

UTAH GYPSY MOTH 1990

Provo Canyon Application #3

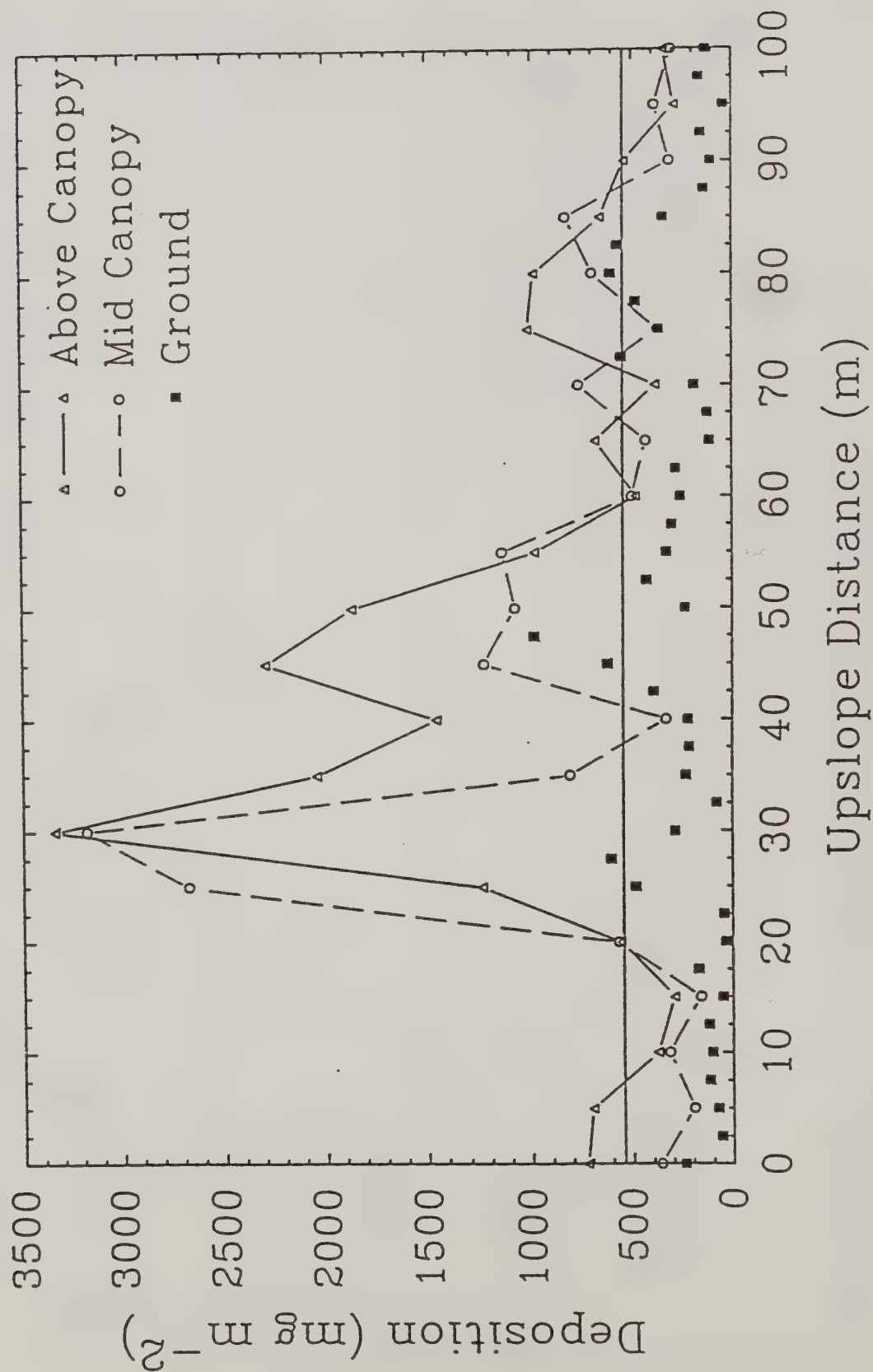


Figure 17. Deposition density vs sampler position for 1990 Provo application #3.

Table 2. Mean card deposition and canopy penetration ratios for 1990 spray trials.

1990 TRIALS	DEPOSITION (mg/m**2)			PENETRATION RATIO		
	CANOPY LEVEL TOP	MID	GROUND	TOP	MID	GROUND
OLYMPUS #1	466.3	373.0	105.3	1.00	0.80	0.23
OLYMPUS #2	329.4	218.7	172.8	1.00	0.66	0.53
OLYMPUS #3	235.9	253.1	98.4	1.00	1.07	0.42
MEAN	343.9	281.6	125.5	1.00	0.82	0.37
PARLEY'S #1	191.4	174.5	143.4	1.00	0.91	0.75
PARLEY'S #2	457.6	301.5	134.4	1.00	0.66	0.29
PARLEY'S #3	565.1	283.7	206.9	1.00	0.50	0.37
MEAN	404.7	253.2	161.6	1.00	0.63	0.40
PROVO #1	271.0	353.6	204.7	1.00	1.31	0.76
PROVO #2	425.5	111.0	66.3	1.00	0.26	0.16
PROVO #3	1009.5	791.4	269.6	1.00	0.78	0.27
MEAN	568.7	418.7	180.2	1.00	0.74	0.32

LAI-2000 PLANT CANOPY ANALYZER MEASUREMENTS

Below/Above Canopy Radiation Ratios				
1990 Sites		Angle from Zenith (deg)		
	7	23	38	53
				68
Olympus Cove		Using 1/2 sky from 226 to 064 degrees azimuth		
18 Jun	Mean	0.255	0.305	0.243
	Std. Dev.	0.203	0.180	0.156
				0.196
				0.109
				0.150
				0.082
Lamb's Canyon				
22 Jun	Mean	0.586	0.549	0.489
	Std. Dev.	0.317	0.291	0.291
				0.416
				0.262
				0.277
				0.195
Provo Canyon		Using 1/2 sky from 190 to 010 degrees azimuth		
23 Jun	Mean	0.497	0.442	0.392
	Std. Dev.	0.313	0.261	0.241
				0.333
				0.172
				0.257
				0.125

Table 3. LAI-2000 plant canopy analyzer measurements for the 1990 sites taken at full leaf emergence in the spring of 1991.

HAND COUNTED CARD SAMPLES
 Gypsy Moth - Mountain Dell Block
 Application #1 - Sampling Line #1

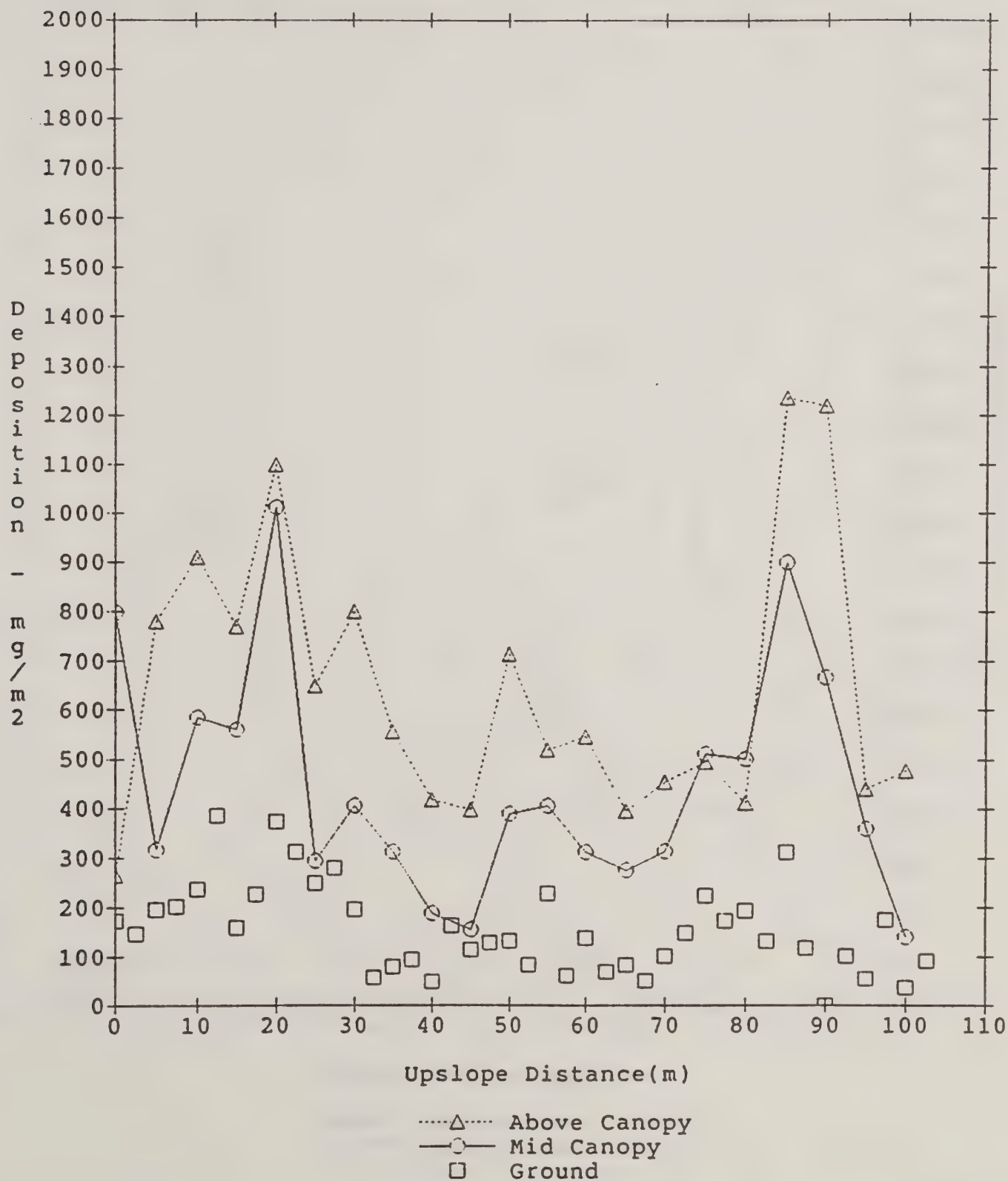


Figure 18. Deposition density vs sampler position for 1991 Parley's application #1 line #1.

HAND COUNTED CARD SAMPLES
Gypsy Moth - Mountain Dell Block
Application #1 - Sampling Line #2

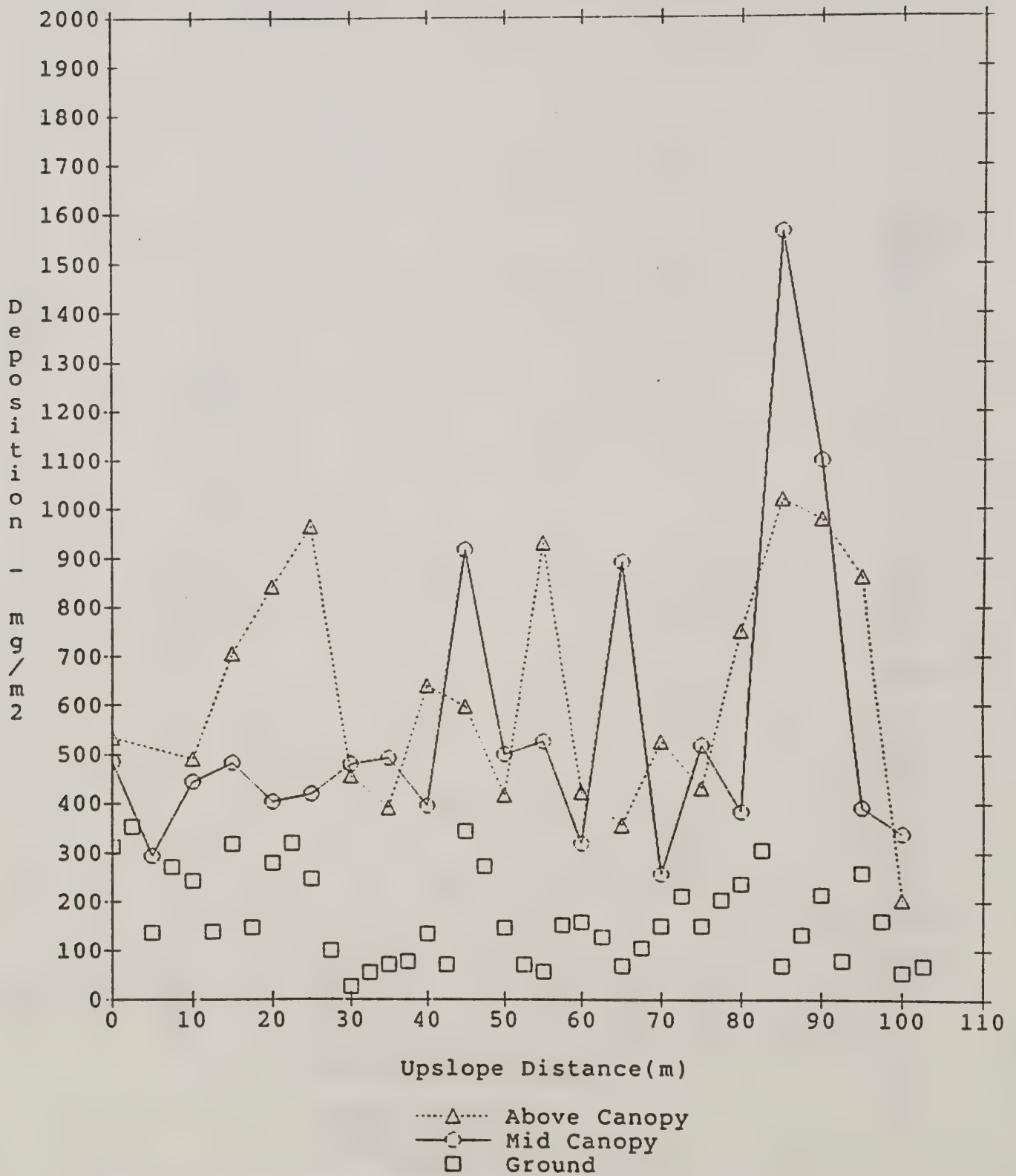


Figure 19. Deposition density vs sampler position for 1991 Parley's application #1 line #2.

HAND COUNTED CARD SAMPLES
 Gypsy Moth - Mountain Dell Block
 Application #2 - Sampling Line #1

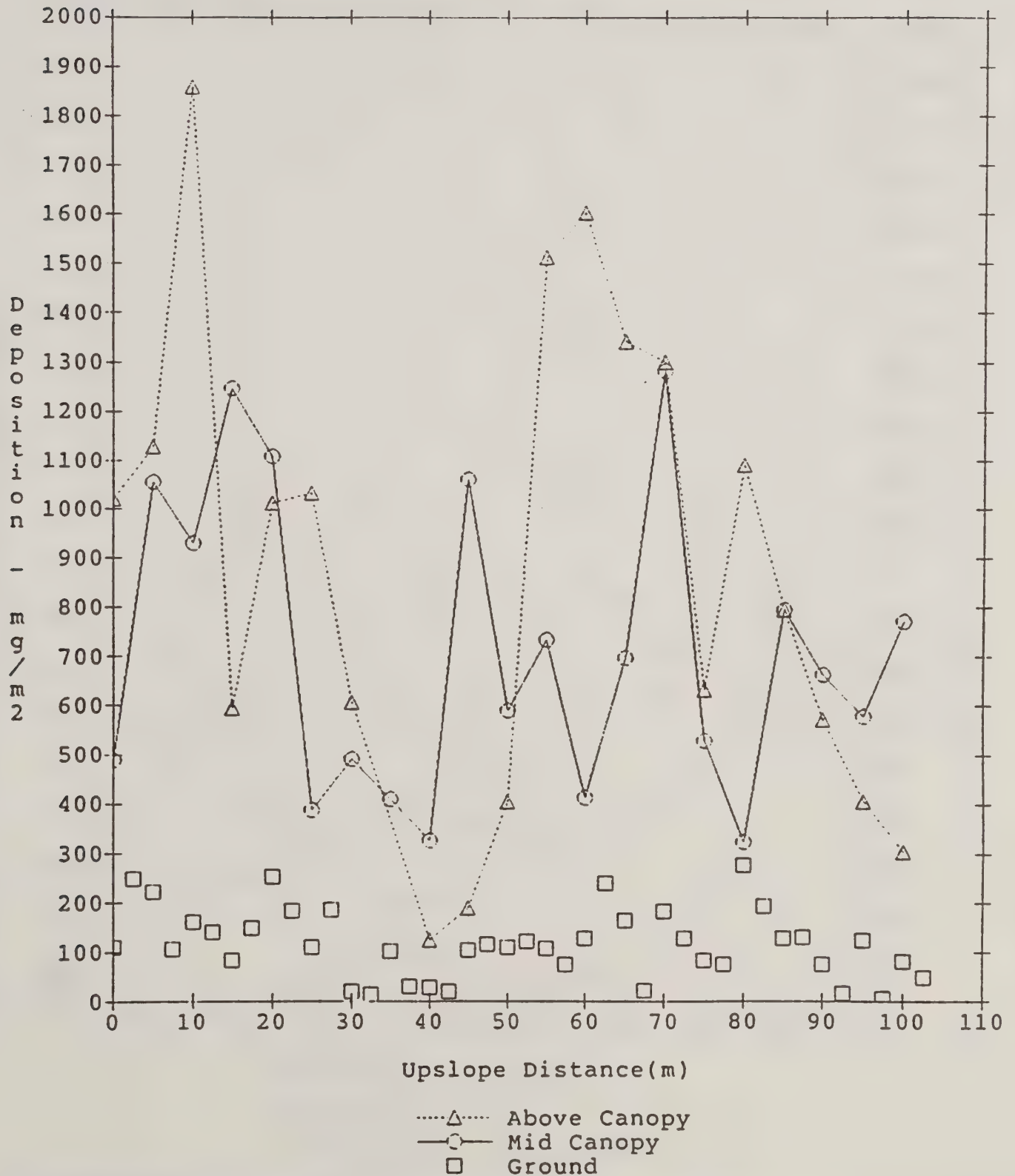


Figure 20. Deposition density vs sampler position for 1991 Parley's application #2 line #1.

HAND COUNTED CARD SAMPLES
 Gypsy Moth - Mountain Dell Block
 Application #2 - Sampling Line #2

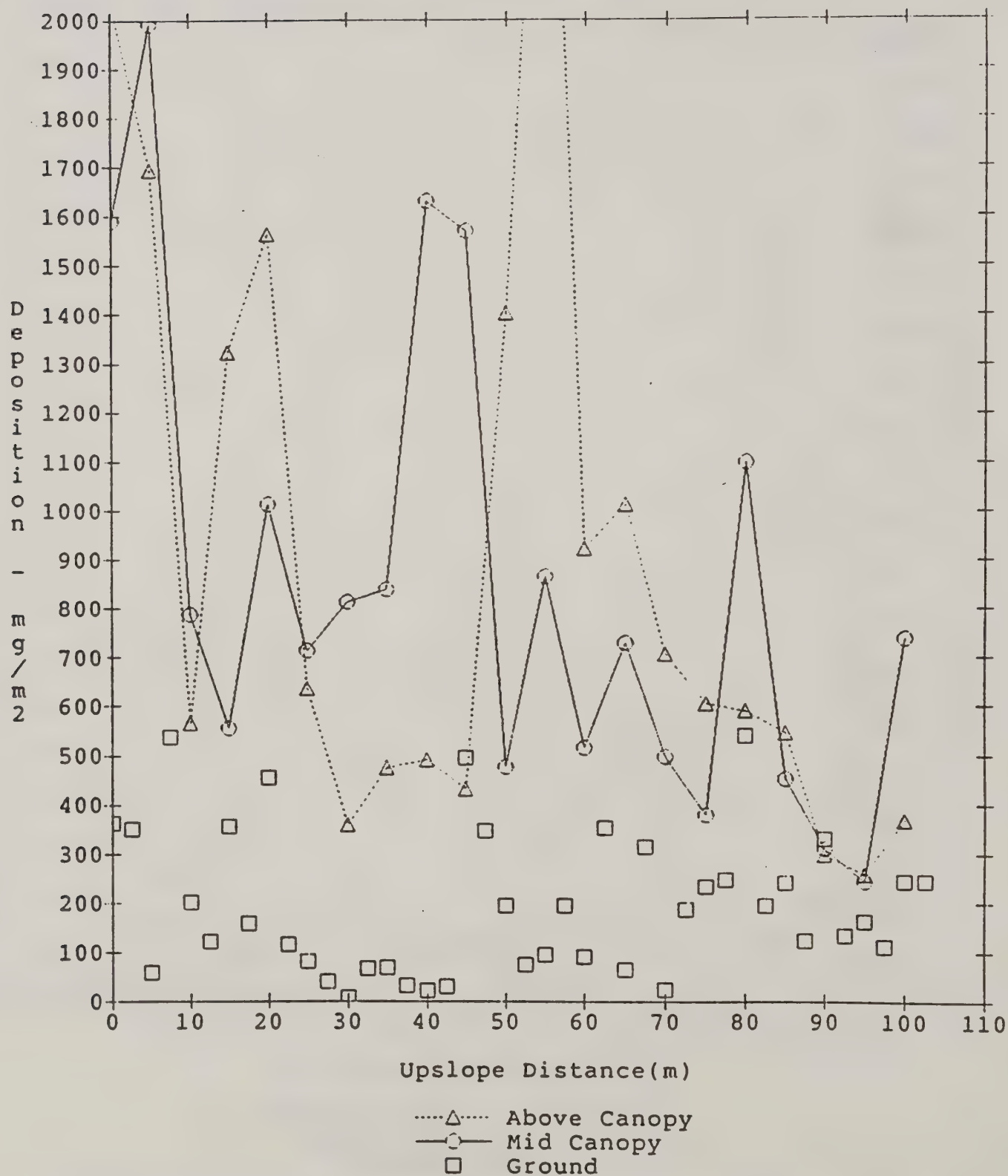


Figure 21. Deposition density vs sampler position for 1991 Parley's application #2 line #2.

HAND COUNTED CARD SAMPLES
 Gypsy Moth - Mountain Dell Block
 Application #3 - Sampling Line #1

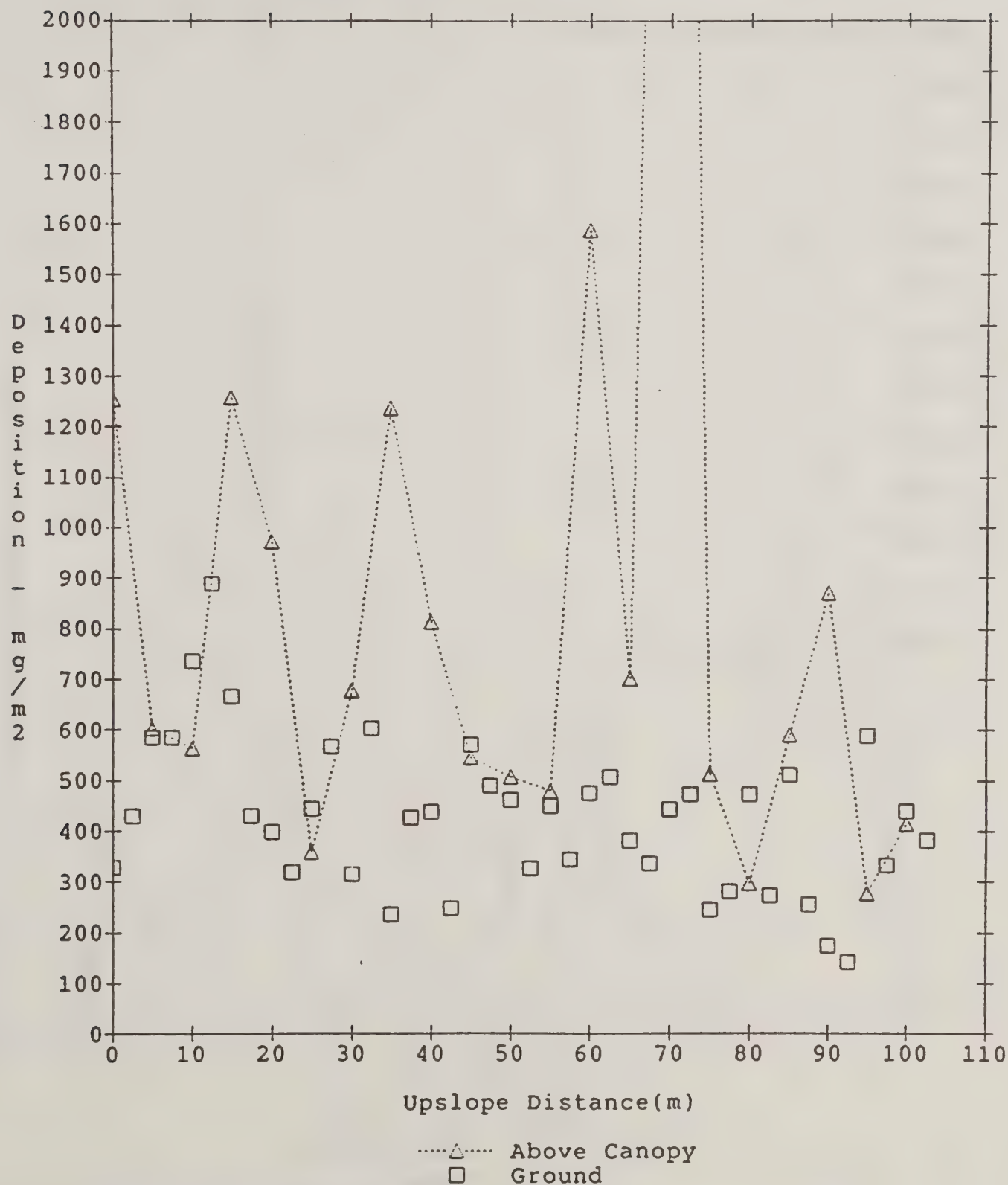


Figure 22. Deposition density vs sampler position for 1991 Parley's application #3 line #1.

HAND COUNTED CARD SAMPLES
Gypsy Moth - Mountain Dell Block
Application #3 - Sampling Line #2

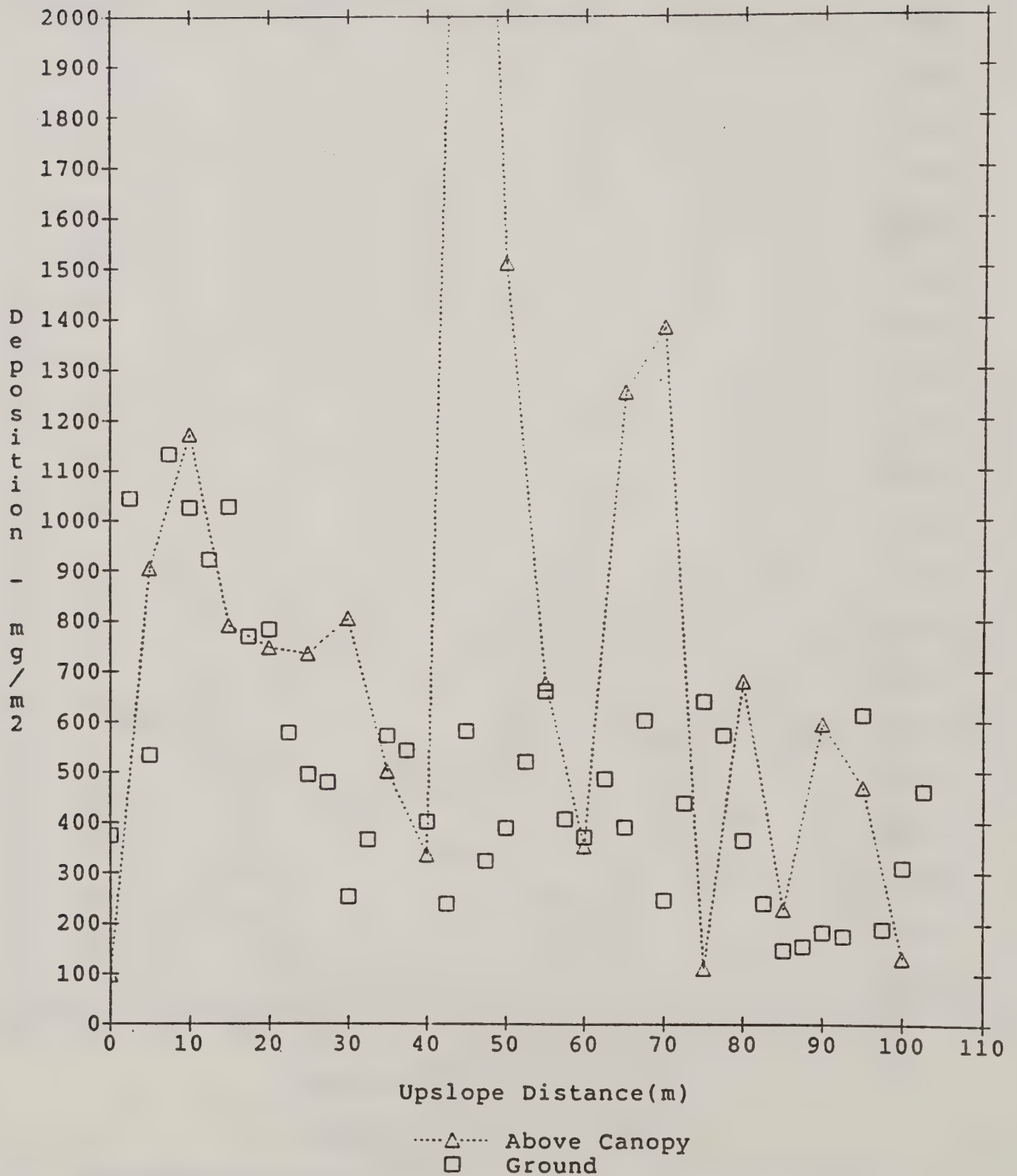


Figure 23. Deposition density vs sampler position for 1991 Parley's application #3 line #2.

MACHINE COUNTED CARD SAMPLES
Gypsy Moth - Mountain Dell Block
Application #1 - Sampling Line #1

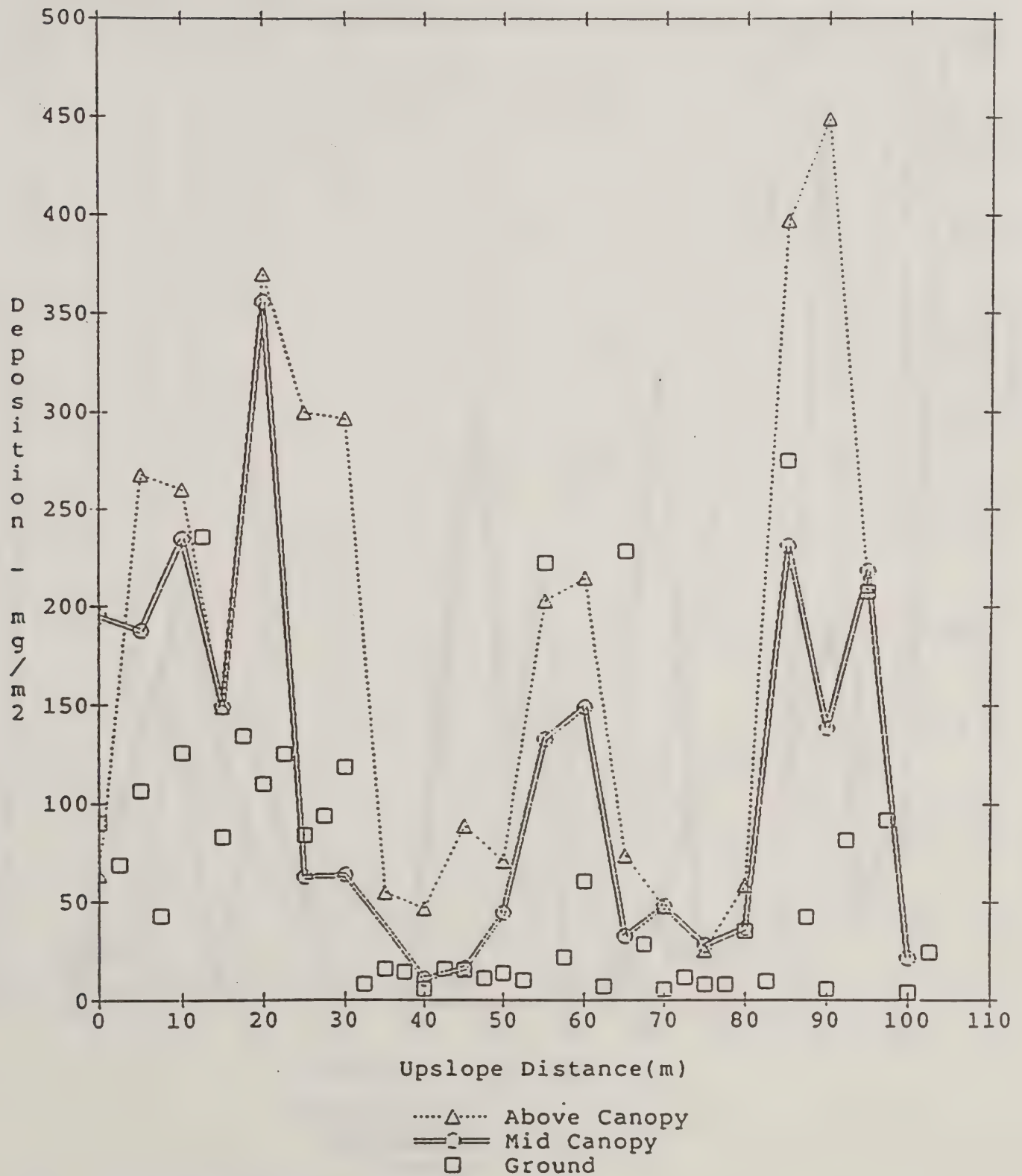


Figure 24. Deposition density vs sampler position for 1991 Parley's application #1 line #1.

MACHINE COUNTED CARD SAMPLES
 Gypsy Moth - Mountain Dell Block
 Application #1 - Sampling Line #2

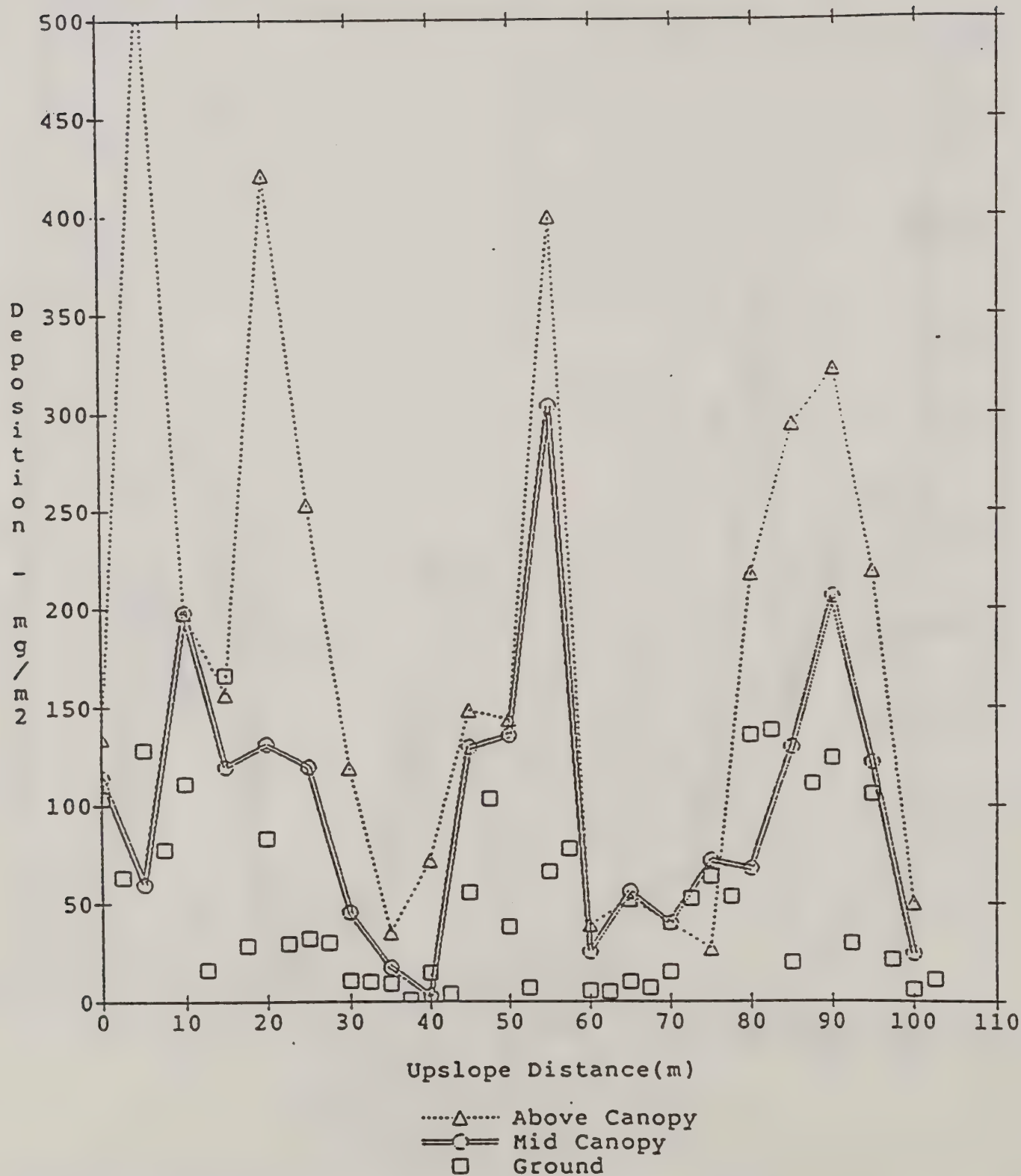


Figure 25. Deposition density vs sampler position for 1991 Parley's application #1 line #2.

MACHINE COUNTED CARD SAMPLES
Gypsy Moth - Mountain Dell Block
Application #2 - Sampling Line #1

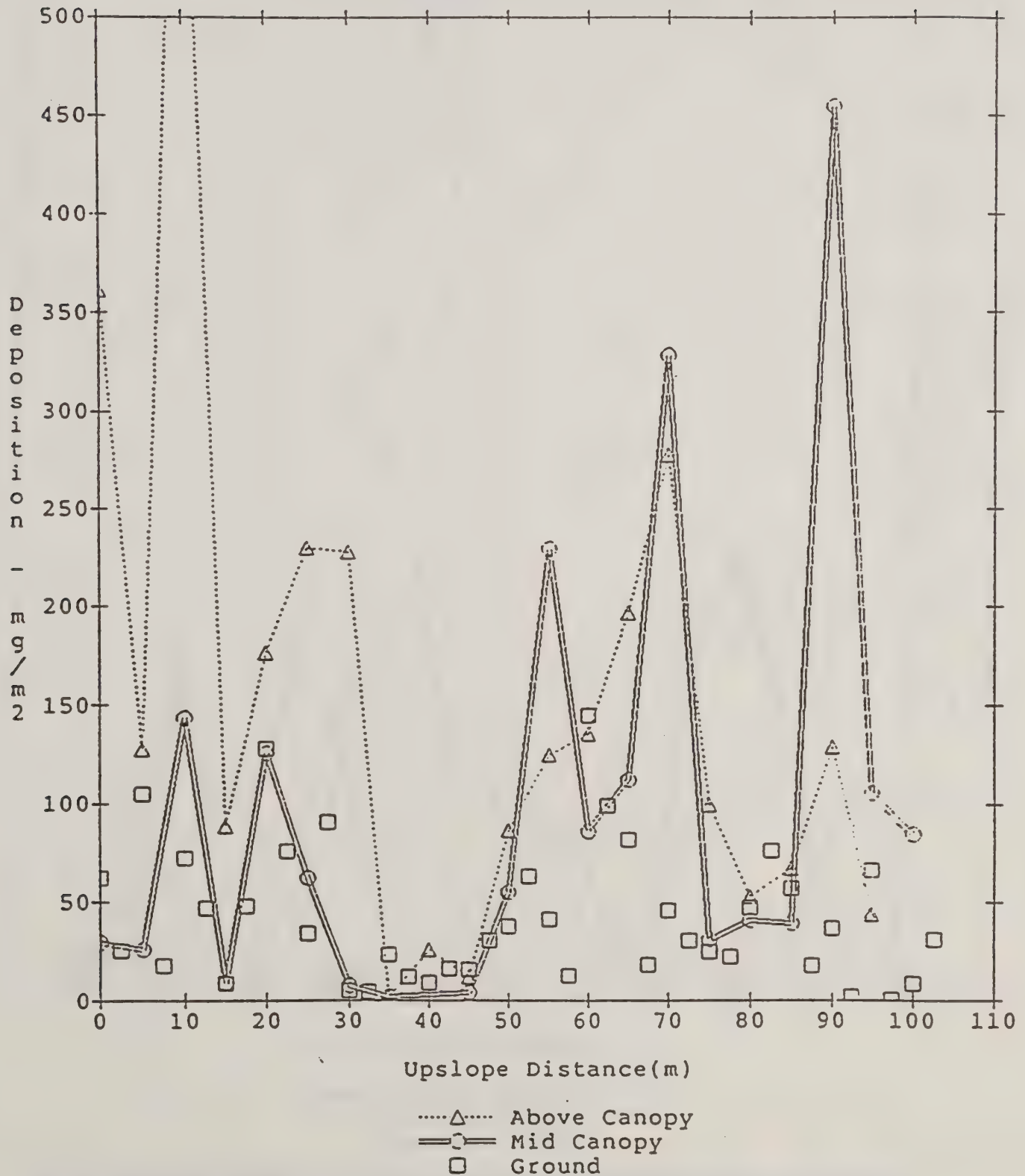


Figure 26. Deposition density vs sampler position for 1991 Parley's application #2 line #1.

MACHINE COUNTED CARD SAMPLES
 Gypsy Moth - Mountain Dell Block
 Application #2 - Sampling Line #2

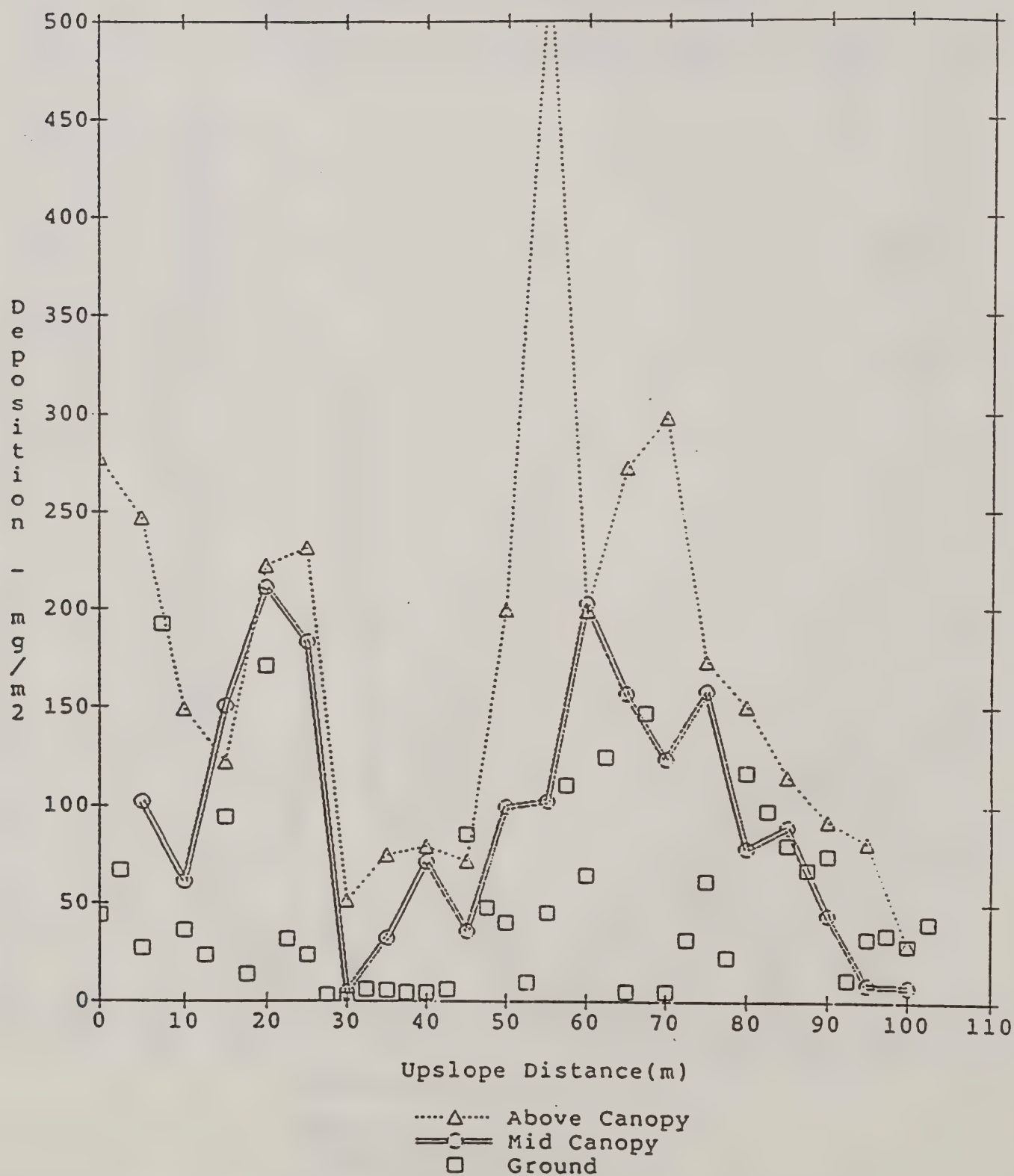


Figure 27. Deposition density vs sampler position for 1991 Parley's application #2 line #2.

MACHINE COUNTED CARD SAMPLES
 Gypsy Moth - Mountain Dell Block
 Application #3 - Sampling Line #1

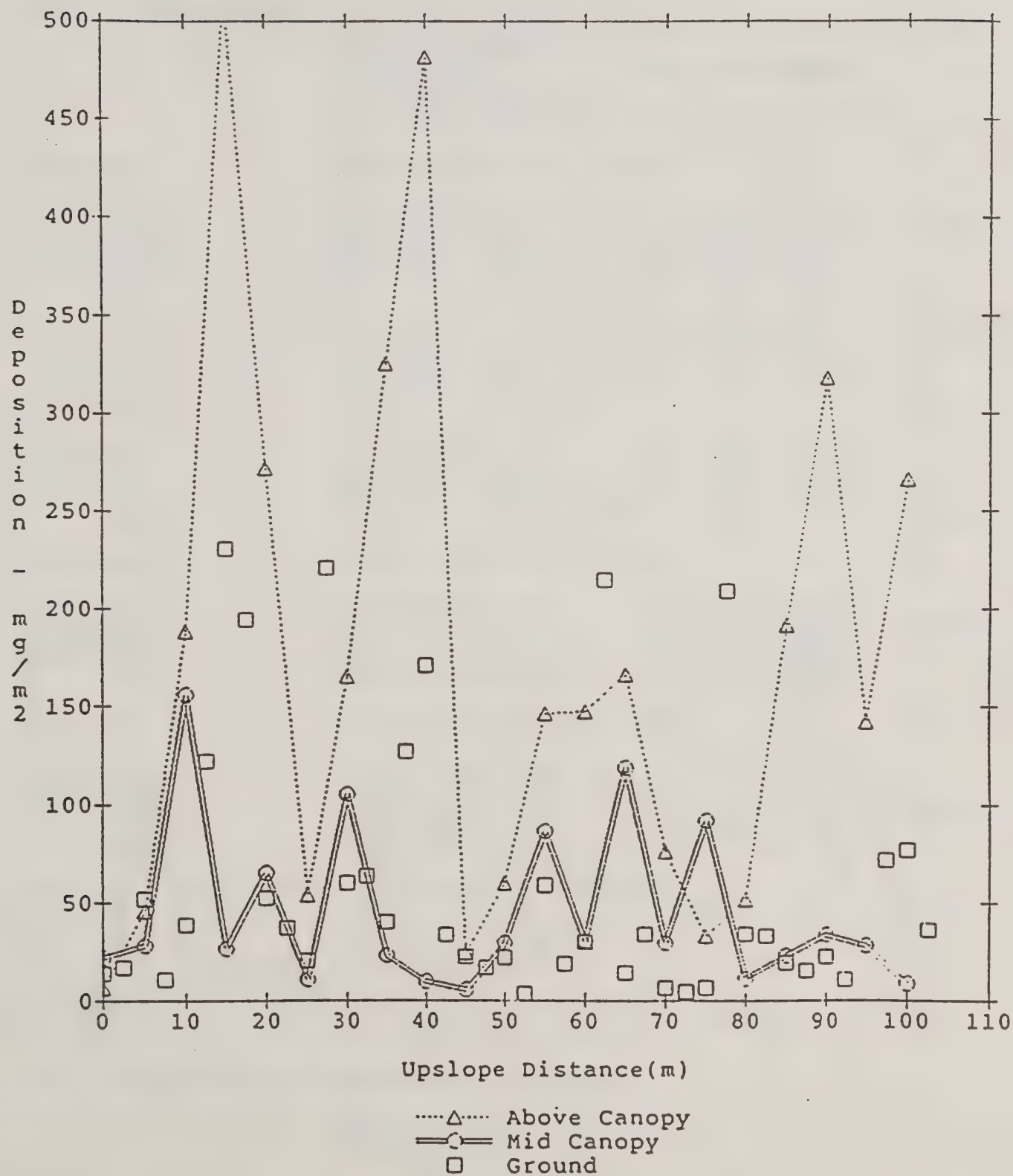


Figure 28. Deposition density vs sampler position for 1991 Parley's application #3 line #1.

MACHINE COUNTED CARD SAMPLES
Gypsy Moth - Mountain Dell Block
Application #3 - Sampling Line #2

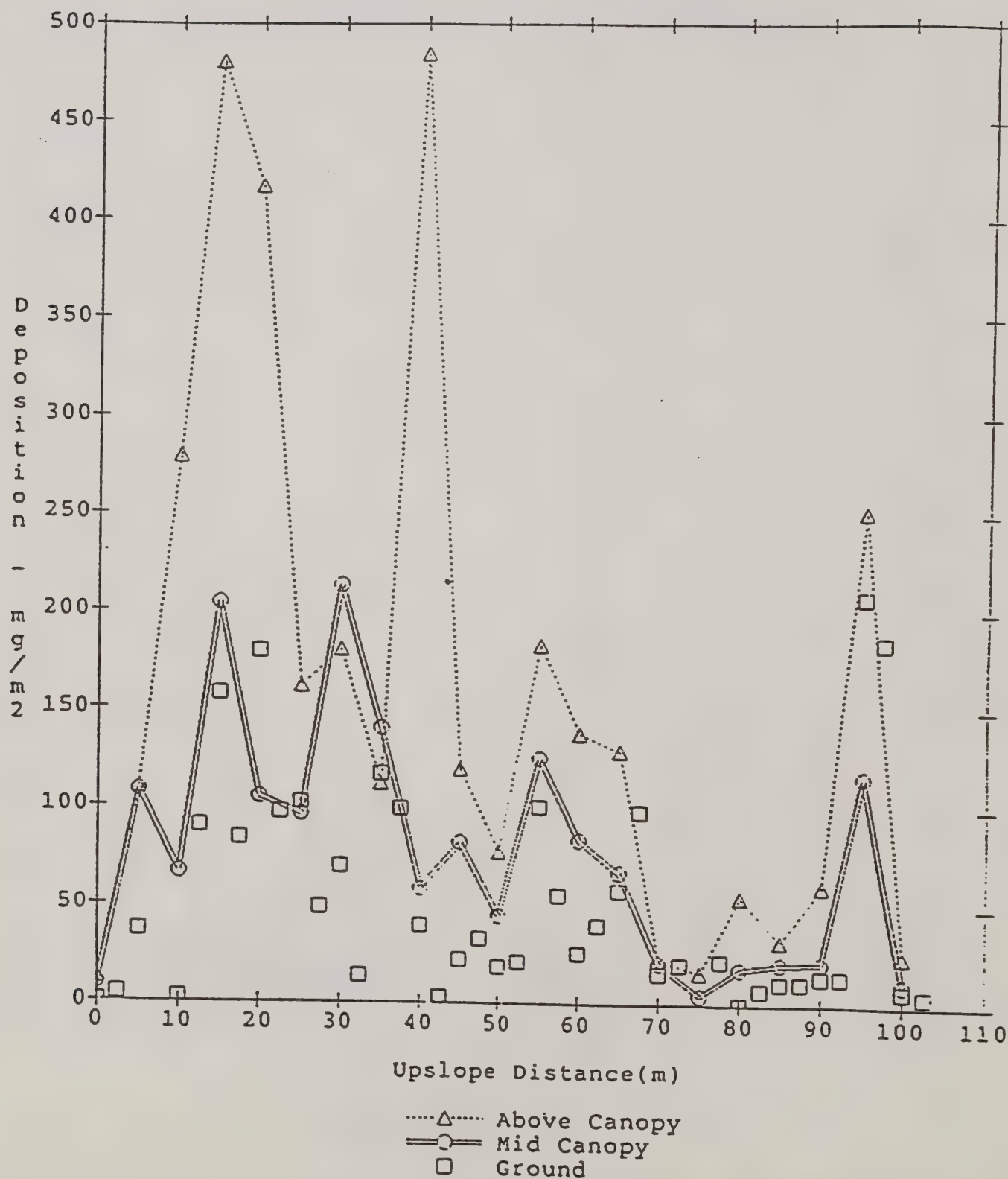


Figure 29. Deposition density vs sampler position for 1991 Parley's application #3 line #1.

TABLE 4. Mean card deposition and canopy penetration ratios.

	DEPOSITION (mg/m**2)			PENETRATION RATIO		
	CANOPY LEVEL					
	TOP	MID	GROUND	TOP	MID	GROUND
1990 TRIALS	HAND COUNTED CARD SAMPLES					
OLYMPUS #1	466.3	373.0	105.3	1.00	0.80	0.23
OLYMPUS #2	329.4	218.7	172.8	1.00	0.66	0.53
OLYMPUS #3	235.9	253.1	98.4	1.00	1.07	0.42
MEAN	343.9	281.6	125.5	1.00	0.82	0.37
PARLEY'S #1	191.4	174.5	143.4	1.00	0.91	0.75
PARLEY'S #2	457.6	301.5	134.4	1.00	0.66	0.29
PARLEY'S #3	565.1	283.7	206.9	1.00	0.50	0.37
MEAN	404.7	253.2	161.6	1.00	0.63	0.40
PROVO #1	271.0	353.6	204.7	1.00	1.31	0.76
PROVO #2	425.5	111.0	66.3	1.00	0.26	0.16
PROVO #3	1009.5	791.4	269.6	1.00	0.78	0.27
MEAN	568.7	418.7	180.2	1.00	0.74	0.32
1991 TRIALS	HAND COUNTED CARD SAMPLES					
PARLEY'S #1	636.4	500.5	162.7	1.00	0.79	0.26
PARLEY'S #2	894.3	779.5	158.2	1.00	0.87	0.18
PARLEY'S #3	863.0	ND	464.6	1.00	ND	0.54
MEAN	797.9	640.0	261.8	1.00	0.83	0.33
1991 TRIALS	MACHINE COUNTED CARD SAMPLES					
PARLEY'S #1	183.2	109.5	60.7	1.00	0.60	0.33
PARLEY'S #2	166.5	97.6	47.0	1.00	0.59	0.28
PARLEY'S #3	167.4	61.1	57.1	1.00	0.37	0.34
MEAN	172.4	89.4	54.9	1.00	0.52	0.32
MEAN PENETRATION RATIOS FOR ALL DATA SETS COMBINED:				1.00	0.71	0.35

ND = NO DATA AVAILABLE

LAI-2000 PLANT CANOPY ANALYZER MEASUREMENTS

		Below/Above Canopy Radiation Ratios					
1991 Site		7	Angle from Zenith (deg)				
			23	30	53	68	
04 Jun	Mean	0.648	0.622	0.546	0.434	0.270	
	Std. Dev.	0.156	0.124	0.121	0.080	0.043	
09 Jun	Mean	0.577	0.554	0.470	0.360	0.214	
	Std. Dev.	0.193	0.142	0.134	0.085	0.041	
14 Jun	Mean	0.444	0.423	0.331	0.228	0.120	
	Std. Dev.	0.224	0.161	0.135	0.073	0.041	
18 Jun	Mean	0.302	0.378	0.287	0.209	0.118	
	Std. Dev.	0.240	0.166	0.128	0.082	0.047	

Table 5. LAI-2000 plant canopy analyzer measurements for the 1991 trials in Parley's canyon.

APPENDIX A

SUMMARY OF METEOROLOGICAL DATA FOR AERIAL SPRAY TRIALS IN GAMBEL OAK

18 March 1992

METEOROLOGICAL MEASUREMENTS MADE DURING THE 1990 AND 1991
GYPSY MOTH CANOPY PENETRATION EXPERIMENTS

During both years of the gypsy moth canopy penetration experiments, meteorological observations were made by the TECOM meteorological team of Dugway Proving Ground. Wind speed and direction was measured using an anemometer and wind vane on a 2-m mast in an open area near the deposition grid at each site. We were able to select a site with an open area of at least 10 m in radius at each site except the Olympus Cove site of the 1990 experiment. At Olympus Cove a bend in a dirt road was selected which afforded an opening in the forest of approximately 4 m in radius. Wind speeds and directions were recorded on strip charts and averaged for ten minutes starting at the beginning of spray dissemination at each canopy penetration site. Surface observations including dry and wet bulb temperatures and were made at half hour intervals during the spray period. The following tables list the observations made closest to the beginning of spray dissemination at the canopy penetration grids.

1990 METEOROLOGICAL DATA

Site	Olympus Cove			Lamb's Canyon			Provo Canyon		
	1	2	3	1	2	3	1	2	3
Application									
Spray Time (MDT)	0910	0948	0759	0925	0730	1024	0740	0620	0652
Wind Speed (m s ⁻¹)	0.4	0.2	0.9	ND ^b	2.7	3.6	0.9	0.9	1.1
Wind Direction (deg)	270	330	180	ND	140	305	150	45	VAR
Temperature (C)	9	17	12	ND	12	14	6	7	6
Relative Humidity (%)	59	43	58	ND	58	56	80	71	65
Cloud Cover (tenths)	7	0	0	ND	3	8	0	0	7
Cloud Height (m)	3050	--	--	ND	3050	6100	--	--	2130
Pressure ^a (mb)	810	810	810	805	805	805	800	800	800

a No atmospheric pressures were measured during the 1990 trials. The pressures given in the table are estimates based on the site elevation.

b No Data (observer was not available)

1991 METEOROLOGICAL DATA

Application	1	2	3
Date	10 June	15 June	19 June
Time (MDT)	0626	0600	0618
Wind Speed (m s ⁻¹)	ND ^a	1.3	1.6
Wind Direction (deg)	ND	180	230
Relative Humidity (%)	ND	44	14
Temperature (C)	ND	5.3	19.4
Cloud Cover (tenths)	ND	0	10
Ceiling (m)	ND	--	7620
Pressure (mb)	ND	820.1	814.2

a No Data (observer was not available)

APPENDIX B

SUMMARY OF DEPOSITION CARD DATA (HAND COUNT) FOR AERIAL SPRAY TRIALS
CONDUCTED IN GAMBEL OAK IN 1990

HAND COUNTED CARD SAMPLES
Gypsy Moth, Olympus Block, Canopy Penetration,
Application #1, June 2, 1990

Position	Deposition Density (mg/m ²)			
	Ground	Ground (Between Poles)	Mid	Top
1	1.7		11.1	14.5
2		348.4		
3	93.5		554.2	639.6
4		76.7		
5	12.4		145.3	1216.4
6		46.6		
7	228.7		707.4	666.4
8		680.5		
9	471.5		577.9	1176.9
10		81.5		
11	79.2		460.6	274.8
12		69.2		
13	9.6		312.4	115.3
14		30.9		
15	81.9		781.1	370.0
16		99.3		
17	67.7		803.0	620.3
18		143.3		
19	38.6		152.9	359.1
20		37.0		
21	19.2		43.3	399.7
22		179.8		
23	12.6		234.4	547.5
24		144.6		
25	44.4		345.4	374.6
26		30.1		
27	18.5		207.6	443.8
28		16.8		
29	221.5		366.7	193.6
30		25.4		
31	84.4		541.8	432.4
32		24.8		
33	50.1		77.3	396.3
34		13.5		
35	29.4		273.4	89.8
36		31.4		
37	71.3		641.3	228.3
38		7.8		
39	27.5		310.8	421.9
40		532.7		
41	33.8		285.6	810.1
<hr/>				
Mean	105.3		373.0	466.3
Ratio to Top	0.23		0.80	1.00

HAND COUNTED CARD SAMPLES
Gypsy Moth, Olympus Block, Canopy Penetration,
Application #2, June 7, 1990

Position	Deposition Density (mg/m ²)			
	Ground	Ground (Between Poles)	Mid	Top
1	65.9		91.1	229.1
2		62.9		
3	62.9		182.9	137.5
4		40.0		
5	97.1		14.5	113.8
6		201.7		
7	118.8		168.7	184.5
8		320.7		
9	96.9		31.5	129.1
10		194.0		
11	117.5		324.6	575.8
12		547.7		
13	83.5		362.2	281.5
14		293.4		
15	145.3		284.1	270.2
16		145.3		
17	112.5		114.4	212.9
18		300.6		
19	320.0		148.4	521.5
20		165.9		
21	146.4		163.9	352.3
22		217.5		
23	113.4		1.5	95.6
24		180.6		
25	483.4		82.7	174.5
26		227.9		
27	62.9		183.2	311.6
28		139.2		
29	263.2		29.6	338.5
30		133.1		
31	139.4		267.2	418.2
32		76.3		
33	111.3		282.2	952.6
34		154.8		
35	77.4		467.2	628.2
36		127.1		
37	278.4		429.6	434.7
38		221.6		
39	133.4		608.2	300.8
40		131.4		
41	173.3		355.2	253.6
<hr/>				
Mean	172.8		218.7	329.4
Ratio to Top	0.52		0.66	1.00

HAND COUNTED CARD SAMPLES
Gypsy Moth, Olympus Block, Canopy Penetration,
Application #1, June 2, 1990

Position	Deposition Density (mg/m ²)			
	Ground	Ground (Between Poles)	Mid	Top
1	108.8		204.9	525.8
2		111.9		
3	89.9		395.0	205.4
4		111.3		
5	201.0		634.4	361.1
6		214.3		
7	498.5		715.6	379.0
8		620.6		
9	425.6		251.5	267.2
10		83.6		
11	433.0		527.0	199.7
12		69.6		
13	84.4		189.1	317.8
14		0.7		
15	98.6		652.4	797.7
16		164.4		
17	95.1		277.7	488.5
18		175.8		
19	20.8		158.4	203.4
20		16.6		
21	0.2		142.3	130.8
22		7.4		
23	2.5		65.6	138.8
24		105.0		
25	63.3		281.9	616.6
26		9.2		
27	37.0		101.4	25.7
28		0.0		
29	7.4		23.8	26.7
30		16.4		
31	17.9		57.4	7.8
32		0.0		
33	0.0		49.6	62.3
34		12.6		
35	16.2		226.5	29.4
36		0.0		
37	16.2		197.5	78.5
38		29.6		
39	0.0		10.1	35.5
40		49.2		
41	20.6		152.5	56.2
<hr/>				
Mean	98.4		253.1	235.9
Ratio to Top	0.42		1.07	1.00

HAND COUNTED CARD SAMPLES
Gypsy Moth, Lamb's Canyon Block, Canopy Penetration,
Application #1, May 31, 1990

Position	Deposition Density (mg/m ²)			
	Ground	Ground (Between Poles)	Mid	Top
1	218.0		363.9	141.1
2		277.6		
3	17.9		204.3	180.4
4		221.8		
5	130.0		265.7	50.3
6		105.9		
7	61.7		95.0	2.1
8		50.8		
9	75.6		133.4	22.3
10		43.8		
11	47.1		41.1	42.5
12		7.2		
13	12.4		552.5	304.7
14		39.3		
15	30.9		105.0	271.3
16		49.2		
17	7.2		63.0	244.0
18		73.6		
19	99.6		175.7	226.6
20		180.6		
21	147.2		46.6	122.0
22		144.7		
23	121.6		59.3	147.2
24		173.4		
25	322.5		552.5	304.7
26		455.3		
27	272.9		447.5	735.5
28		146.1		
29	152.2		114.2	284.7
30		95.9		
31	71.0		38.3	158.5
32		101.3		
33	166.0		52.1	127.4
34		71.9		
35	121.5		54.7	129.9
36		267.4		
37	171.9		170.3	128.9
38		211.2		
39	288.1		149.9	335.4
40		355.4		
41	273.7		349.4	209.7
Mean	143.4		174.5	191.4
Ratio to Top	0.75		0.91	1.00

HAND COUNTED CARD SAMPLES
Gypsy Moth, Lamb's Canyon Block, Canopy Penetration,
Application #2, June 7, 1990

Position	Deposition Density (mg/m ²)			
	Ground	Ground (Between Poles)	Mid	Top
1	198.3		535.3	1465.7
2		280.0		
3	125.4		528.3	398.0
4		233.4		
5	220.1		389.0	386.6
6		151.9		
7	79.0		410.8	519.9
8		255.9		
9	219.7		608.7	246.7
10		201.9		
11	72.6		108.4	755.6
12		154.4		
13	51.7		248.4	241.8
14		69.0		
15	7.7		114.5	199.5
16		29.2		
17	90.0		77.0	314.4
18		112.1		
19	108.0		117.4	229.7
20		180.2		
21	71.8		35.6	428.1
22		41.1		
23	53.5		120.9	214.5
24		57.9		
25	34.5		98.8	216.9
26		86.8		
27	37.2		40.9	101.4
28		32.6		
29	31.5		108.7	181.3
30		71.7		
31	123.3		531.5	313.8
32		35.4		
33	191.9		394.9	315.4
34		262.0		
35	45.1		960.9	630.7
36		522.5		
37	52.0		119.3	985.8
38		46.8		
39	77.4		335.1	329.8
40		297.0		
41	495.9		446.7	1135.4
<hr/>				
Mean	134.4		301.5	457.6
Ratio to Top	0.29		0.66	1.00

HAND COUNTED CARD SAMPLES
Gypsy Moth, Lamb's Canyon Block, Canopy Penetration,
Application #3, June 13, 1990

Position	Deposition Density (mg/m ²)			
	Ground	Ground (Between Poles)	Mid	Top
1	360.9		594.4	971.5
2		154.5		
3	120.4		248.9	520.0
4		169.4		
5	145.2		282.2	293.6
6		244.0		
7	36.8		346.9	508.1
8		62.0		
9	233.6		359.9	438.9
10		7.2		
11	0.0		0.0	165.6
12		16.2		
13	7.2		7.2	104.9
14		29.6		
15	194.1		106.0	252.9
16		89.1		
17	63.5		35.1	1210.9
18		96.9		
19	43.3		129.5	994.6
20		36.1		
21	103.2		95.0	397.9
22		90.1		
23	83.7		93.3	248.0
24		15.9		
25	90.6		79.3	682.5
26		30.6		
27	106.6		266.6	442.6
28		0.5		
29	10.7		57.6	332.8
30		16.2		
31	216.1		32.1	538.6
32		434.6		
33	487.0		472.4	421.6
34		458.9		
35	482.0		950.9	1378.0
36		689.5		
37	744.2		487.5	437.2
38		367.7		
39	145.8		665.2	623.7
40		1192.6		
41	605.8		646.8	902.6
Mean	206.9		283.7	565.1
Ratio to Top	0.37		0.50	1.00

HAND COUNTED CARD SAMPLES
 Gypsy Moth, Provo Block, Canopy Penetration,
 Application #1, June 3, 1990

Position	Deposition Density (mg/m ²)			
	Ground	Ground (Between Poles)	Mid	Top
1	421.2		514.8	312.6
2		271.1		
3	497.5		243.8	332.2
4		79.9		
5	226.4		302.7	395.5
6		204.0		
7	201.5		273.6	179.1
8		108.9		
9	74.0		351.1	152.8
10		30.4		
11	96.6		190.4	90.0
12		103.5		
13	147.8		236.5	120.8
14		51.8		
15	312.6		342.5	157.8
16		109.9		
17	127.7		523.5	486.9
18		212.6		
19	279.1		537.3	567.5
20		163.5		
21	147.7		349.5	292.8
22		186.0		
23	240.0		365.7	187.1
24		408.4		
25	497.6		165.6	274.2
26		165.7		
27	533.4		541.7	145.9
28		367.3		
29	378.4		407.7	312.5
30		187.4		
31	155.0		467.8	249.7
32		126.1		
33	214.6		675.3	166.8
34		84.8		
35	55.3		142.6	293.8
36		92.2		
37	41.2		358.8	187.8
38		211.4		
39	197.7		301.1	319.0
40		264.8		
41	117.3		335.1	263.4
Mean	204.7		353.6	271.0
Ratio to Top	0.76		1.30	1.00

HAND COUNTED CARD SAMPLES
Gypsy Moth, Provo Block, Canopy Penetration,
Application #2, June 7, 1990

Position	Deposition Density (mg/m ²)			
	Ground	Ground (Between Poles)	Mid	Top
1	9.0		329.4	526.7
2		130.8		
3	145.8		229.1	1136.2
4		9.5		
5	101.8		71.9	1055.0
6		23.2		
7	24.0		50.6	626.4
8		13.3		
9	40.8		56.9	833.2
10		66.9		
11	6.1		113.3	527.7
12		86.5		
13	66.2		142.7	314.2
14		2.1		
15	101.0		141.4	454.0
16		27.3		
17	93.6		101.2	289.7
18		89.4		
19	0.0		53.4	768.7
20		106.5		
21	218.2		97.6	271.7
22		88.5		
23	33.5		123.8	88.4
24		119.4		
25	106.7		45.2	194.0
26		27.7		
27	105.7		58.2	200.5
28		79.7		
29	37.5		226.3	80.0
30		77.4		
31	17.0		180.0	296.1
32		26.1		
33	55.8		18.9	244.8
34		191.4		
35	20.4		16.7	98.6
36		26.3		
37	41.5		52.8	79.1
38		102.8		
39	ND		ND	ND
40		ND		
41	ND		ND	ND
Mean	66.3		111.0	425.5
Ratio to Top	0.16		0.26	1.00

HAND COUNTED CARD SAMPLES
Gypsy Moth, Provo Block, Canopy Penetration,
Application #3, June 13, 1990

Position	Deposition Density (mg/m ²)			
	Ground	Ground (Between Poles)	Mid	Top
1	240.7		361.1	727.0
2		59.1		
3	76.5		193.1	697.0
4		116.4		
5	103.4		316.2	373.4
6		119.4		
7	51.0		158.9	291.3
8		171.6		
9	36.7		565.7	554.4
10		44.5		
11	484.3		2672.4	1239.3
12		604.4		
13	286.6		3179.7	3342.2
14		80.5		
15	233.2		808.5	2039.5
16		216.2		
17	222.2		331.1	1451.5
18		393.9		
19	620.3		1229.0	2290.5
20		983.5		
21	234.9		1077.0	1863.6
22		427.8		
23	329.1		1141.0	978.3
24		301.3		
25	258.3		497.8	478.8
26		281.3		
27	111.7		427.6	678.5
28		121.9		
29	188.8		762.8	380.9
30		550.2		
31	364.8		371.6	1011.7
32		480.6		
33	604.3		695.9	982.4
34		569.4		
35	344.3		828.7	653.6
36		139.8		
37	105.4		311.9	536.1
38		154.6		
39	43.5		385.9	287.3
40		165.1		
41	131.1		303.3	342.6
Mean	269.6		791.4	1009.5
Ratio to Top	0.27		0.78	1.00

APPENDIX C

SUMMARY OF DEPOSITON CARD DATA (MACHINE/HAND COUNT) FOR AERIAL SPRAY TRIALS
CONDUCTED IN GAMBEL OAK IN 1991

MACHINE COUNTED CARD SAMPLES

Gypsy Moth, Mountain Dell Block, Canopy Penetration,
Droplet Mass Median Diameter (MMD) (μm).

	Application Number		
	1	2	3
Top Canopy	316	296	295
Mid Canopy	311	355	298
Ground	295	284	294
Over All	310	286	295

MACHINE COUNTED CARD SAMPLES
Gypsy Moth, Mountain Dell Block, Canopy Penetration,
Application #1, Sampling Line #1, June 10, 1991

Position	Deposition Density (mg/m ²)			
	Ground	Ground (Between Poles)	Mid	Top
1	90.24		195.00	63.58
2		68.94		
3	106.58		187.88	267.80
4		42.85		
5	125.90		234.93	260.41
6		235.93		
7	83.17		149.40	149.00
8		134.33		
9	109.92		355.67	370.30
10		125.16		
11	83.93		62.54	299.11
12		93.64		
13	118.80		63.69	296.30
14		8.22		
15	15.72			54.83
16		14.58		
17	5.74		10.82	46.47
18		15.69		
19	15.25		16.19	88.93
20		11.29		
21	13.86		44.45	71.11
22		10.32		
23	222.53		133.15	202.94
24		21.77		
25	60.88		149.39	215.12
26		7.04		
27	228.41		32.84	74.07
28		28.48		
29	5.66		47.78	47.58
30		11.88		
31	8.25		28.25	25.37
32		8.19		
33	35.03		36.66	58.59
34		10.03		
35	274.71		231.17	397.26
36		42.47		
37	5.90		138.32	448.64
38		81.45		
39	207.61		218.43	210.63
40		91.65		
41	4.36		21.52	
42		24.44		
Mean	86.78	51.83	117.90	182.40
Std. Dev.	84.68	58.38	96.23	132.91
Ratio to Top	0.38		0.65	1.00

MACHINE COUNTED CARD SAMPLES
Gypsy Moth, Mountain Dell Block, Canopy Penetration,
Application #1, Sampling Line #2, June 10, 1991

Position	Deposition Density (mg/m ²)			
	Ground	Ground (Between Poles)	Mid	Top
43	103.49		114.34	134.32
44		63.48		
45	128.42		59.69	521.23
46		77.24		
47	110.85		198.00	197.96
48		16.55		
49	166.63		119.82	157.01
50		28.66		
51	83.17		131.27	421.26
52		29.41		
53	32.31		119.92	253.12
54		29.98		
55	11.04		45.58	119.40
56		10.22		
57	9.23		17.61	35.03
58		1.36		
59	15.07		3.15	71.68
60		4.27		
61	55.38		129.96	148.67
62		103.48		
63	38.28		135.94	144.15
64		7.05		
65	66.35		303.57	399.56
66		77.93		
67	5.96		25.66	39.10
68		5.43		
69	10.44		55.98	51.99
70		7.15		
71	15.26		40.33	40.32
72		52.37		
73	63.80		71.67	26.90
74		53.60		
75	135.97		68.02	218.04
76		138.40		
77	19.81		129.75	294.23
78		111.06		
79	124.43		206.28	322.12
80		29.54		
81	105.59		121.93	218.75
82		21.37		
83	6.44		24.38	50.12
84		11.25		
Mean	62.28	41.90	101.09	184.05
Std. Dev.	51.54	39.74	73.20	141.73
Ratio to Top	0.28		0.55	1.00

MACHINE COUNTED CARD SAMPLES
Gypsy Moth, Mountain Dell Block, Canopy Penetration,
Application #2, Sampling Line #1, June 15, 1991

Position	Deposition Density (mg/m ²)			
	Ground	Ground (Between Poles)	Mid	Top
1	62.19		29.79	361.27
2		25.75		
3	105.15		26.04	127.98
4		17.79		
5	72.46		143.72	693.93
6		47.18		
7	8.70		9.22	88.53
8		47.79		
9	128.57		126.02	176.92
10		75.94		
11	34.16		61.96	230.19
12		90.48		
13	5.27		7.55	228.33
14		4.68		
15	23.65		1.93	2.32
16		12.23		
17	9.28			25.92
18		16.27		
19	16.09		4.03	12.22
20		30.69		
21	37.67		55.30	86.60
22		63.19		
23	41.17		229.54	125.23
24		12.88		
25	145.29		86.20	136.02
26		99.35		
27	82.00		112.79	197.27
28		18.54		
29	46.04		328.31	278.17
30		30.65		
31	24.85		31.36	100.01
32		22.67		
33	47.64		40.66	53.01
34		76.58		
35	57.25		39.07	67.25
36		18.03		
37	36.81		454.59	129.37
38		2.27		
39	66.52		105.37	43.98
40		0.69		
41	8.79		84.61	
42		31.23		
<hr/>				
Mean	50.45	35.47	98.90	158.23
Std. Dev.	39.06	29.49	116.81	156.74
Ratio to Top		0.27	0.63	1.00

MACHINE COUNTED CARD SAMPLES

Gypsy Moth, Mountain Dell Block, Canopy Penetration,
Application #2, Sampling Line #2, June 15, 1991

Position	Deposition Density (mg/m ²)			
	Ground	Ground (Between Poles)	Mid	Top
43	43.67			277.72
44		66.59		
45	26.98		101.78	247.02
46		192.57		
47	36.07		61.14	149.43
48		23.74		
49	94.42		150.82	122.14
50		13.74		
51	171.34		211.23	222.65
52		31.48		
53	23.79		183.23	231.58
54		3.04		
55	0.76		4.58	51.47
56		6.23		
57	5.64		32.36	75.15
58		4.89		
59	4.77		71.54	79.68
60		5.99		
61	85.60		35.94	72.11
62		47.81		
63	40.43		99.90	199.88
64		9.97		
65	45.18		102.76	528.26
66		111.18		
67	64.74		203.42	199.81
68		125.39		
69	5.36		157.50	272.81
70		147.77		
71	5.33		124.38	298.24
72		31.92		
73	61.54		158.47	173.66
74		22.61		
75	117.29		78.35	150.52
76		97.95		
77	80.02		89.41	115.29
78		67.46		
79	74.28		43.64	92.16
80		11.12		
81	32.22		8.54	80.97
82		34.26		
83	28.56		7.78	29.12
84		40.15		
Mean	49.90	52.18	96.34	174.75
Std. Dev.	43.07	53.42	65.04	114.34
Ratio to Top	0.29		0.55	1.00

MACHINE COUNTED CARD SAMPLES
Gypsy Moth, Mountain Dell Block, Canopy Penetration,
Application #3, Sampling Line #1, June 19, 1991

Position	Deposition Density (mg/m ²)			
	Ground	Ground (Between Poles)	Mid	Top
1	13.78		21.95	6.70
2		17.00		
3	52.03		27.92	45.89
4		10.92		
5	39.02		155.71	188.37
6		122.31		
7	230.83		26.74	514.68
8		194.56		
9	52.79		65.02	271.80
10		37.18		
11	20.61		10.60	54.01
12		221.16		
13	60.23		105.51	165.46
14		63.64		
15	40.45		22.83	325.23
16		127.21		
17	171.32		9.72	481.53
18		33.89		
19	22.74		5.54	24.67
20		16.95		
21	22.10		29.45	60.30
22		3.67		
23	59.12		86.59	146.60
24		19.05		
25	30.23		30.50	147.66
26		214.95		
27	14.34		119.28	166.31
28		34.14		
29	6.72		29.57	76.46
30		4.57		
31	6.73		92.13	33.07
32		209.37		
33	34.02		11.57	51.90
34		33.39		
35	19.57		22.91	191.87
36		15.54		
37	22.41		33.88	318.23
38		10.66		
39			28.29	142.52
40		71.90		
41	76.80		8.77	266.40
42		36.18		
Mean	49.79	71.34	44.98	175.22
Std. Dev.	56.00	76.76	42.09	143.84
Ratio to Top		0.35	0.26	1.00

MACHINE COUNTED CARD SAMPLES
Gypsy Moth, Mountain Dell Block, Canopy Penetration,
Application #3, Sampling Line #2, June 19, 1991

Position	Deposition Density (mg/m ²)			
	Ground	Ground (Between Poles)	Mid	Top
43	0.74		9.55	12.12
44		4.61		
45	37.28		108.23	109.42
46				
47	2.48		66.56	279.77
48		90.32		
49	157.64		204.36	480.55
50		83.95		
51	179.91		105.08	416.88
52		97.55		
53	102.39		96.53	161.76
54		48.80		
55	69.87		213.56	180.54
56		13.62		
57	117.31		140.52	112.18
58		99.33		
59	40.06		58.74	484.41
60		3.02		
61	22.38		81.88	119.55
62		33.31		
63	19.21		44.75	77.23
64		21.52		
65	100.15		125.12	183.22
66		55.54		
67	26.22		83.78	138.20
68		40.42		
69	58.21		67.47	129.33
70		98.51		
71	15.74		20.78	23.01
72		20.62		
73			4.82	16.52
74		22.44		
75	0.76		18.29	55.01
76		7.65		
77	11.52		20.82	32.49
78		11.22		
79	14.61		21.74	60.90
80		14.54		
81	208.00		116.02	251.69
82		185.01		
83	7.51		11.55	25.77
84		5.27		
Mean	59.60	47.86	77.15	159.55
Std. Dev.	63.74	47.54	60.58	146.42
Ratio to Top	0.34		0.48	1.00

HAND COUNTED CARD SAMPLES
Gypsy Moth, Mountain Dell Block, Canopy Penetration,
Application #1, Sampling Line #1, June 10, 1991

Position	Deposition Density (mg/m ²)			
	Ground	Ground (Between Poles)	Mid	Top
1	173.23		799.03	265.86
2		147.14		
3	195.90		316.46	780.29
4		202.47		
5	237.18		584.60	910.54
6		384.27		
7	159.44		560.77	769.81
8		226.42		
9	372.72		1012.57	1098.78
10		312.32		
11	248.93		293.47	650.17
12		279.33		
13	196.14		406.15	799.74
14		57.37		
15	80.88		311.24	555.95
16		94.94		
17	48.77		187.81	418.06
18		162.48		
19	115.02		155.74	397.98
20		129.09		
21	132.79		389.14	715.76
22		83.47		
23	228.53		405.83	518.66
24		60.80		
25	139.36		311.44	546.55
26		68.85		
27	83.47		274.47	395.51
28		51.91		
29	103.27		314.91	455.47
30		149.17		
31	224.22		512.29	495.63
32		173.51		
33	194.03		501.56	410.77
34		133.51		
35	312.28		900.82	1236.80
36		118.73		
37	0.00		667.85	1219.35
38		101.96		
39	55.78		359.13	441.05
40		175.23		
41	37.57		140.56	476.11
42		92.07		
Mean	159.02	152.62	447.90	645.66
Std. Dev.	94.18	88.12	236.92	278.81
Ratio to Top	0.24		0.69	1.00

HAND COUNTED CARD SAMPLES
Gypsy Moth, Mountain Dell Block, Canopy Penetration,
Application #1, Sampling Line #2, June 10, 1991

Position	Deposition Density (mg/m ²)			
	Ground	Ground (Between Poles)	Mid	Top
43	312.92		484.47	534.31
44		352.56		
45	135.94		293.63	
46		271.88		
47	242.63		444.74	490.17
48		137.97		
49	318.50		482.04	707.71
50		147.14		
51	280.37		404.07	843.65
52		320.53		
53	246.98		420.85	965.32
54		100.96		
55	26.10		481.40	457.02
56		54.78		
57	72.27		493.24	391.25
58		77.45		
59	134.83		394.94	641.38
60		71.99		
61	344.24		918.31	598.07
62		273.63		
63	147.14		502.12	418.73
64		71.99		
65	57.65		527.34	933.08
66		153.99		
67	159.44		320.37	424.63
68		129.09		
69	68.85		893.57	357.10
70		106.14		
71	152.04		256.42	527.10
72		212.56		
73	152.04		519.05	431.69
74		203.95		
75	236.34		383.48	754.19
76		306.74		
77	69.40		1566.65	1019.82
78		133.63		
79	213.75		1099.60	980.18
80		80.60		
81	258.66		391.45	863.49
82		161.76		
83	54.50		339.41	204.51
84		68.85		
Mean	175.46	163.72	553.20	627.17
Std. Dev.	97.47	92.45	315.01	241.64
Ratio to Top	0.27		0.88	1.00

HAND COUNTED CARD SAMPLES
Gypsy Moth, Mountain Dell Block, Canopy Penetration,
Application #2, Sampling Line #1, June 15, 1991

Position	Deposition Density (mg/m ²)			
	Ground	Ground (Between Poles)	Mid	Top
1	110.40		489.88	1021.17
2		248.17		
3	223.39		1055.02	1128.99
4		106.70		
5	161.44		931.54	1858.34
6		140.08		
7	83.75		1247.09	595.27
8		149.69		
9	253.74		1107.23	1013.12
10		183.78		
11	110.68		388.17	1031.68
12		184.79		
13	20.08		490.26	608.03
14		14.34		
15	102.51		409.68	
16		31.83		
17	28.69		326.57	123.91
18		20.08		
19	104.38		1062.04	189.33
20		116.30		
21	111.40		590.10	406.59
22		122.59		
23	109.29		734.96	1513.13
24		75.14		
25	127.89		413.63	1603.56
26		241.28		
27	166.30		698.97	1342.23
28		22.95		
29	183.78		1283.60	1300.70
30		129.61		
31	83.15		529.24	633.45
32		76.70		
33	277.54		324.98	1092.28
34		193.23		
35	128.17		797.37	795.55
36		131.04		
37	75.14		664.24	572.71
38		17.21		
39	124.15		577.94	404.99
40		5.74		
41	81.43		772.13	302.95
42		49.32		
Mean	127.01	107.65	709.27	876.90
Std. Dev.	65.52	75.53	301.64	491.43
Ratio to Top		0.13	0.81	1.00

HAND COUNTED CARD SAMPLES
Gypsy Moth, Mountain Dell Block, Canopy Penetration,
Application #2, Sampling Line #2, June 15, 1991

Position	Deposition Density (mg/m ²)			
	Ground	Ground (Between Poles)	Mid	Top
43	362.44		1590.02	2037.66
44		351.52		
45	60.52		1990.44	1695.03
46		537.27		
47	202.44		788.61	565.55
48		123.59		
49	357.66		555.42	1323.44
50		158.69		
51	457.46		1014.51	1562.86
52		116.86		
53	82.15		714.66	637.35
54		40.72		
55	8.61		815.19	361.00
56		67.09		
57	70.24		841.01	477.69
58		32.11		
59	23.23		1630.31	492.95
60		31.83		
61	498.13		1569.39	434.10
62		348.21		
63	195.26		478.57	1402.12
64		75.42		
65	95.94		868.50	2832.03
66		195.54		
67	92.63		518.42	925.30
68		354.66		
69	66.54		731.81	1014.63
70		316.83		
71	25.82		499.77	709.10
72		188.13		
73	235.14		381.72	606.94
74		248.37		
75	541.32		1100.62	593.55
76		195.70		
77	243.10		453.99	548.66
78		124.46		
79	331.49		312.24	298.77
80		135.66		
81	164.35		245.50	259.48
82		112.71		
83	245.59		740.30	369.32
84		244.63		
Mean	207.62	190.48	849.57	911.79
Std. Dev.	163.40	131.49	479.70	669.56
Ratio to Top		0.21	0.93	1.00

HAND COUNTED CARD SAMPLES
Gypsy Moth, Mountain Dell Block, Canopy Penetration,
Application #3, Sampling Line #1, June 19, 1991

Position	Deposition Density (mg/m ²)			
	Ground	Ground (Between Poles)	Mid	Top
1	328.33			1253.91
2		430.12		
3	585.39			603.11
4		583.88		
5	736.62			562.60
6		888.58		
7	666.78			1258.13
8		430.17		
9	398.01			972.52
10		318.89		
11	443.63			357.66
12		567.47		
13	313.87			677.66
14		601.88		
15	235.42			1235.58
16		426.67		
17	437.49			812.75
18		247.06		
19	570.84			545.46
20		488.33		
21	462.23			507.65
22		327.22		
23	449.72			478.85
24		344.62		
25	475.06			1587.53
26		507.18		
27	382.19			701.01
28		336.73		
29	442.62			4784.38
30		474.18		
31	245.70			513.47
32		280.72		
33	473.79			296.34
34		272.04		
35	511.16			591.20
36		255.78		
37	172.75			871.60
38		142.12		
39	589.13			275.82
40		332.87		
41	438.97			414.60
42		381.43		
Mean	445.70	411.33		919.14
Std. Dev.	139.96	162.95		954.19
Ratio to Top		0.47		1.00

HAND COUNTED CARD SAMPLES
Gypsy Moth, Mountain Dell Block, Canopy Penetration,
Application #3, Sampling Line #2, June 19, 1991

Position	Deposition Density (mg/m ²)			
	Ground	Ground (Between Poles)	Mid	Top
43	374.04			97.53
44		1043.75		
45	533.39			905.39
46		1132.84		
47	1026.45			1172.65
48		923.11		
49	1028.13			792.17
50		769.41		
51	782.71			748.06
52		579.57		
53	494.54			736.67
54		479.80		
55	253.07			805.71
56		365.53		
57	572.82			501.92
58		543.03		
59	401.63			336.10
60		239.21		
61	583.46			3448.04
62		324.63		
63	389.32			1510.35
64		521.00		
65	661.67			678.04
66		408.37		
67	372.47			354.47
68		488.29		
69	391.35			1257.22
70		603.95		
71	247.17			1384.04
72		439.28		
73	642.51			112.43
74		573.94		
75	366.54			682.19
76		240.04		
77	147.14			228.09
78		155.74		
79	182.95			595.71
80		175.06		
81	614.62			468.61
82		189.09		
83	310.61			130.92
84		462.20		
Mean	494.12	507.52		806.97
Std. Dev.	242.67	273.01		729.60
Ratio to Top		0.62		1.00

HAND COUNTED CARD SAMPLES
Gypsy Moth, Mountain Dell Block, Canopy Penetration,
Application #1, Sampling Line #1, June 10, 1991

Position	Deposition Density (drops/m ²)			
	Ground	Ground (Between Poles)	Mid	Top
1	30000		88750	44375
2		26250		
3	36875		46250	110000
4		32500		
5	38125		82500	137500
6		51875		
7	23125		76250	104375
8		34375		
9	66250		135625	162500
10		50625		
11	38750		28750	108750
12		40625		
13	22500		35000	93125
14		12500		
15	13750		28750	88750
16		18750		
17	10625		18750	80000
18		26250		
19	23125		28125	75625
20		28125		
21	23125		46250	129375
22		16250		
23	23750		66250	80625
24		9375		
25	18750		43750	63125
26		15000		
27	16250		46250	68750
28		9375		
29	22500		53125	83750
30		32500		
31	25625		58125	92500
32		28125		
33	33125		72500	85625
34		21875		
35	38125		101250	197500
36		18125		
37	0		89375	166250
38		15000		
39	6875		38125	55625
40		23750		
41	6250		30625	84375
42		18125		
Mean	24643	25208	57827	100595
Std. Dev.	14566	12065	29577	38712
Ratio to Top		0.25	0.57	1.00

HAND COUNTED CARD SAMPLES
Gypsy Moth, Mountain Dell Block, Canopy Penetration,
Application #1, Sampling Line #2, June 10, 1991

Position	Deposition Density (drops/m ²)			
	Ground	Ground (Between Poles)	Mid	Top
43	53750		58750	91250
44		36875		
45	21875		36875	
46		43750		
47	41250		56250	89375
48		28125		
49	52500		64375	123750
50		26250		
51	50000		58125	103750
52		58750		
53	51875		61250	147500
54		18125		
55	3750		43125	76875
56		10000		
57	11875		63125	77500
58		16875		
59	29375		36250	128125
60		13750		
61	75000		145000	120625
62		51875		
63	26250		68750	71875
64		13750		
65	10625		65625	112500
66		20000		
67	23125		56250	75625
68		28125		
69	15000		65000	68125
70		23125		
71	33125		48125	80000
72		44375		
73	33125		74375	84375
74		42500		
75	43750		70000	106250
76		51875		
77	11250		130000	159375
78		17500		
79	20000		84375	134375
80		15625		
81	27500		50625	122500
82		27500		
83	11875		51250	38750
84		15000		
Mean	30804	28750	66071	100625
Std. Dev.	18476	14755	26587	30331
Ratio to Top		0.30	0.66	1.00

HAND COUNTED CARD SAMPLES
Gypsy Moth, Mountain Dell Block, Canopy Penetration,
Application #2, Sampling Line #1, June 15, 1991

Position	Deposition Density (drops/m ²)			
	Ground	Ground (Between Poles)	Mid	Top
1	14375		55000	101250
2		27500		
3	31250		76250	149375
4		19375		
5	16875		71875	174375
6		17500		
7	14375		63125	66875
8		16250		
9	26250		78125	95625
10		18750		
11	12500		25625	77500
12		10000		
13	4375		25000	20625
14		3125		
15	11250		33125	
16		5000		
17	6250		34375	23125
18		4375		
19	15000		72500	41250
20		18125		
21	11250		50625	77500
22		15625		
23	21875		90625	169375
24		12500		
25	16250		50000	180625
26		21250		
27	11250		53750	125625
28		5000		
29	18750		106875	98750
30		11875		
31	5625		45625	70625
32		5625		
33	20000		28750	97500
34		15000		
35	14375		52500	68750
36		15000		
37	12500		71875	55625
38		3750		
39	8750		67500	35625
40		1250		
41	10000		54375	37500
42		6875		
Mean	14435	12083	57500	88375
Std. Dev.	6605	7184	21690	49681
Ratio to Top		0.15	0.65	1.00

HAND COUNTED CARD SAMPLES
Gypsy Moth, Mountain Dell Block, Canopy Penetration,
Application #2, Sampling Line #2, June 15, 1991

Position	Deposition Density (drops/m ²)			
	Ground	Ground (Between Poles)	Mid	Top
43	39375		163125	228750
44		33125		
45	11250		133125	153750
46		27500		
47	20000		55625	45625
48		12500		
49	64375		68750	152500
50		11875		
51	41250		86250	164375
52		14375		
53	8750		41875	44375
54		5000		
55	1875		40000	41875
56		6875		
57	5625		40000	53750
58		3125		
59	3125		98125	70625
60		5000		
61	33750		124375	48125
62		31875		
63	21250		55000	157500
64		10625		
65	15625		88750	283750
66		19375		
67	14375		53125	110625
68		31875		
69	10625		50000	118125
70		21875		
71	5625		51875	72500
72		29375		
73	31875		45625	84375
74		42500		
75	51250		90000	71250
76		21875		
77	18125		31875	36250
78		19375		
79	35625		25625	29375
80		23750		
81	30000		41875	27500
82		18750		
83	19375		56250	45625
84		35000		
Mean	23006	20268	68631	97173
Std. Dev.	16779	11181	36342	69973
Ratio to Top		0.22	0.71	1.00

HAND COUNTED CARD SAMPLES
Gypsy Moth, Mountain Dell Block, Canopy Penetration,
Application #3, Sampling Line #1, June 19, 1991

Position	Deposition Density (drops/m ²)			
	Ground	Ground (Between Poles)	Mid	Top
1	42500			67500
2		55000		
3	64375			57500
4		83750		
5	85000			67500
6		93125		
7	67500			130000
8		61875		
9	51875			106250
10		46250		
11	63750			64375
12		56250		
13	43750			61250
14		75000		
15	30000			96875
16		40000		
17	32500			52500
18		35000		
19	51875			46875
20		61875		
21	41875			55000
22		50000		
23	46250			53125
24		32500		
25	38750			116250
26		36250		
27	22500			54375
28		29375		
29	30625			287500
30		37500		
31	20625			39375
32		31250		
33	31250			29375
34		13750		
35	38750			54375
36		32500		
37	16875			75000
38		23750		
39	35625			24375
40		31875		
41	26250			28750
42		27500		
Mean	42024	45446		74673
Std. Dev.	17244	20550		56185
Ratio to Top		0.59		1.00

HAND COUNTED CARD SAMPLES
Gypsy Moth, Mountain Dell Block, Canopy Penetration,
Application #3, Sampling Line #2, June 19, 1991

Position	Deposition Density (drops/m ²)			
	Ground	Ground (Between Poles)	Mid	Top
43	73750			21250
44		114375		
45	77500			103125
46		110625		
47	91250			121875
48		96250		
49	90625			100625
50		74375		
51	73750			111250
52		43750		
53	40000			128125
54		43125		
55	34375			121875
56		31250		
57	51250			48125
58		52500		
59	27500			50000
60		44375		
61	59375			220000
62		47500		
63	30625			139375
64		61250		
65	51250			60625
66		61875		
67	44375			53125
68		49375		
69	36875			152500
70		51875		
71	30625			92500
72		53125		
73	44375			20625
74		43750		
75	64375			56250
76		38750		
77	26250			23125
78		28125		
79	24375			67500
80		21250		
81	36250			33125
82		13750		
83	16875			19375
84		16875		
Mean	48839	52292		83065
Std. Dev.	22192	27466		52877
Ratio to Top		0.61		1.00

APPENDIX D

TECHNIQUE FOR OBTAINING LAI-2000 MEASUREMENTS FOR USE AS INPUT TO THE FSCBG AERIAL SPRAY MODEL

TECHNIQUE FOR OBTAINING LAI-2000 MEASUREMENTS FOR USE AS INPUT TO THE FSCBG AERIAL SPRAY MODEL

The LAI-2000 plant canopy analyzer is a photometric instrument for making non-destructive measurements of Leaf Area Index (LAI) within vegetative canopies made by LI-COR, 4421 Superior St., P.O. Box 4425, Lincoln, Nebraska 68504. The canopy penetration module of FSCBG Version 4.0 aerial spray model has recently been revised by Continuum Dynamics, Incorporated to accept output from the LAI-2000 plant canopy analyzer, thus avoiding the subjective estimates of forest parameters such as tree stand density, typical tree size envelope and probability of penetration previously required as inputs.

The instrument consists of five silicon light detectors configured as a series of concentric rings which view through a fisheye lens. This results in a light response over a range of five different zenith angles when the instrument is in a leveled position. The light is filtered to make vegetation appear 'black' to the detector, resulting in a measurement of light that is proportional to the fraction of the ring illuminated by sky. If simultaneous measurements are taken with two instruments, one under the canopy and one above the canopy or in an adjacent clearing, the radiation intercepted by the canopy is computed by dividing above-canopy by below-canopy values. These ratios for each concentric ring are used by FSCBG to determine the number of droplets from an aerial spray which penetrate the canopy. FSCBG does not use Leaf Area Index which is computed by the on-board data reduction software of the LAI-2070 control unit. Details of use for the LAI-2000 under various field conditions are covered extensively in LI-COR literature, as is use of the LAI-2070 control unit and will not be repeated here.

The general procedure is to use two instruments simultaneously with one located in a clearing on a tripod for taking above-canopy measurements, while the other instrument is used to take measurements along a transect under the canopy. If only one instrument is available, above-canopy readings must be taken in the clearing before and after the transect in the canopy to obtain average sky readings.

APPENDIX E

STATISTICAL COMPARISON OF THREE SIZES OF DEPOSITION CARDS AS DROPLET COLLECTORS

ANOVA ON CARD SIZE

A two-way factorial analysis of variance was performed. The response variable was deposition density (mg/ sq m), and the main effects were application (trial #) and size of card. The two-way interaction was also tested. The two main effects and the interaction term were all found to be significant, indicating that the means of deposition density were significantly different. In regard to soze of card, the small cards collected a significantly higher deposition density than the medium and large cards. The interaction term reproduced the pattern of differences between sizes only for the second trial application.

Although these results indicate that small cards may collect significantly higher deposition density than medium or large cards, several points indicate a need for caution. First, no reasonable explanation for the higher collection of mass for smaller cards presents itself. Second, the interaction term indicates no stable pattern for collection by card size across applications. Third, the different sizes of cards were laid out in a systematic way over the test collection surface, rather than being randomized. It might be useful to repeat the test with the layout of card size randomized to confirm the different collection behavior of the small cards.

Analysis of Variance for mg/m²

Source of variation	Sum of Squares	d.f.	Mean square	F-ratio	Sig. level
MAIN EFFECTS	15901658	4	3975414.5	172.866	.0000
applicatio	15436283	2	7718141.6	335.615	.0000
size	565808	2	282904.0	12.302	.0000
2-FACTOR INTERACTIONS	683606.67	4	170901.67	7.431	.0000
applicatio	683606.67	4	170901.67	7.431	.0000
size					
RESIDUAL	4714391.2	205	22997.030		
TOTAL (CORR.)	21299656	213			

2 missing values have been excluded.

Table of means for mg/m²

Level	Count	Average	Std. Error (internal)	Std. Error (pooled s)	95 Percent Confidence for mean	
applicatio						
1	72	261.60528	12.252406	17.871855	226.36125	296.84931
2	70	732.77729	31.670434	18.125369	697.03331	768.52126
3	72	98.81750	8.295875	17.871855	63.57347	134.06153
size						
1	70	425.44386	47.239358	18.125369	389.69988	461.18783
2	72	314.52347	32.021369	17.871855	279.27944	349.76750
3	72	344.69569	30.687797	17.871855	309.45166	379.93973
applicatio by size						
1 1	24	311.79125	24.328153	30.954961	250.74680	372.83570
1 2	24	198.05083	9.992531	30.954961	137.00638	259.09529
1 3	24	274.97375	20.140843	30.954961	213.92930	336.01820
2 1	22	916.26636	66.786638	32.331402	852.50751	980.02522
2 2	24	650.95625	39.283281	30.954961	589.91180	712.00070
Total	214	360.95724	10.366425	10.366425	340.51423	381.40026

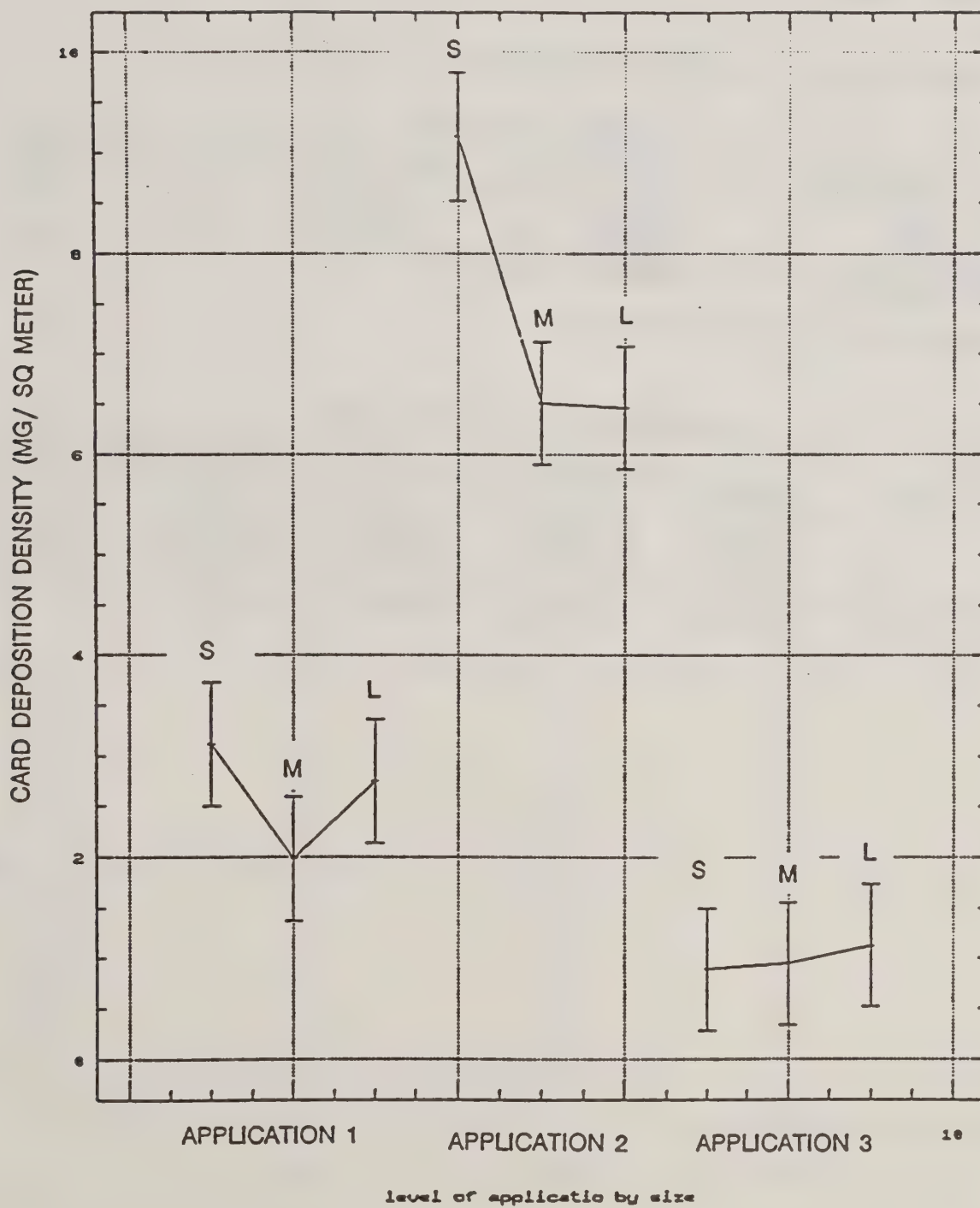
Table of means for mg/m²

Level	Count	Average	Std. Error (internal)	Std. Error (pooled s)	95 Percent Confidence for mean	
2 3	24	646.40000	39.277145	30.954961	585.35555	707.44445
3 1	24	89.17583	11.033627	30.954961	28.13138	150.22029
3 2	24	94.56333	15.433497	30.954961	33.51888	155.60779
3 3	24	112.71333	16.253908	30.954961	51.66888	173.75779
Total	214	360.95724	10.366425	10.366425	340.51423	381.40026

95 Percent Confidence

(X 100)

Intervals for Factor Means



One-Way Analysis of Variance

Data: ALL APPLICATIONS POOLED

Level codes: size

Labels:

Range test: Conf. Int. Confidence level: 95

Analysis of variance

Source of variation	Sum of Squares	d.f.	Mean square	F-ratio	Sig. level
Between groups	465375	2	232687.51	2.357	.0972
Within groups	20834281	211	98740.67		
Total (corrected)	21299656	213			

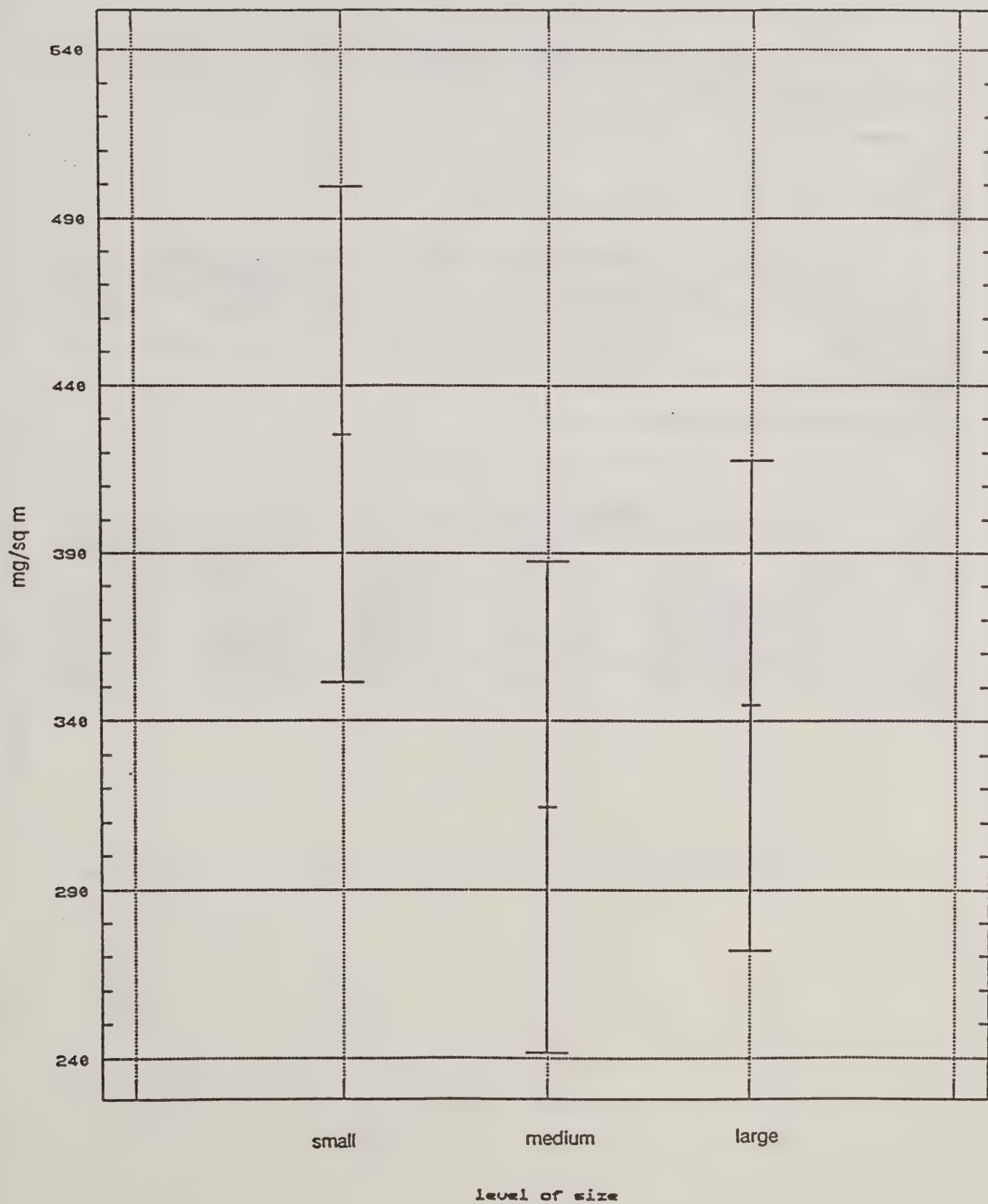
0 missing value(s) have been excluded.

Table of means for mgm2 by size

Level	Count	Average	Std. Error (internal)	Std. Error (pooled s)	95 Percent Confidence intervals for mean	
1	70	425.44386	47.239358	37.557702	351.39103	499.49668
2	72	314.52347	32.021369	37.032394	241.50640	387.54054
3	72	344.69569	30.687797	37.032394	271.67863	417.71276
Total	214	360.95724	21.480340	21.480340	318.60428	403.31020

95 Percent Confidence

Intervals for Factor Means



One-Way Analysis of Variance

Data: mgm2 SELECT applicatio = 1

Level codes: size

Labels:

Range test: Conf. Int. Confidence level: 95

Analysis of variance

Source of variation	Sum of Squares	d.f.	Mean square	F-ratio	Sig. level
Between groups	161676.37	2	80838.183	9.208	.0003
Within groups	605744.52	69	8778.906		
Total (corrected)	767420.89	71			

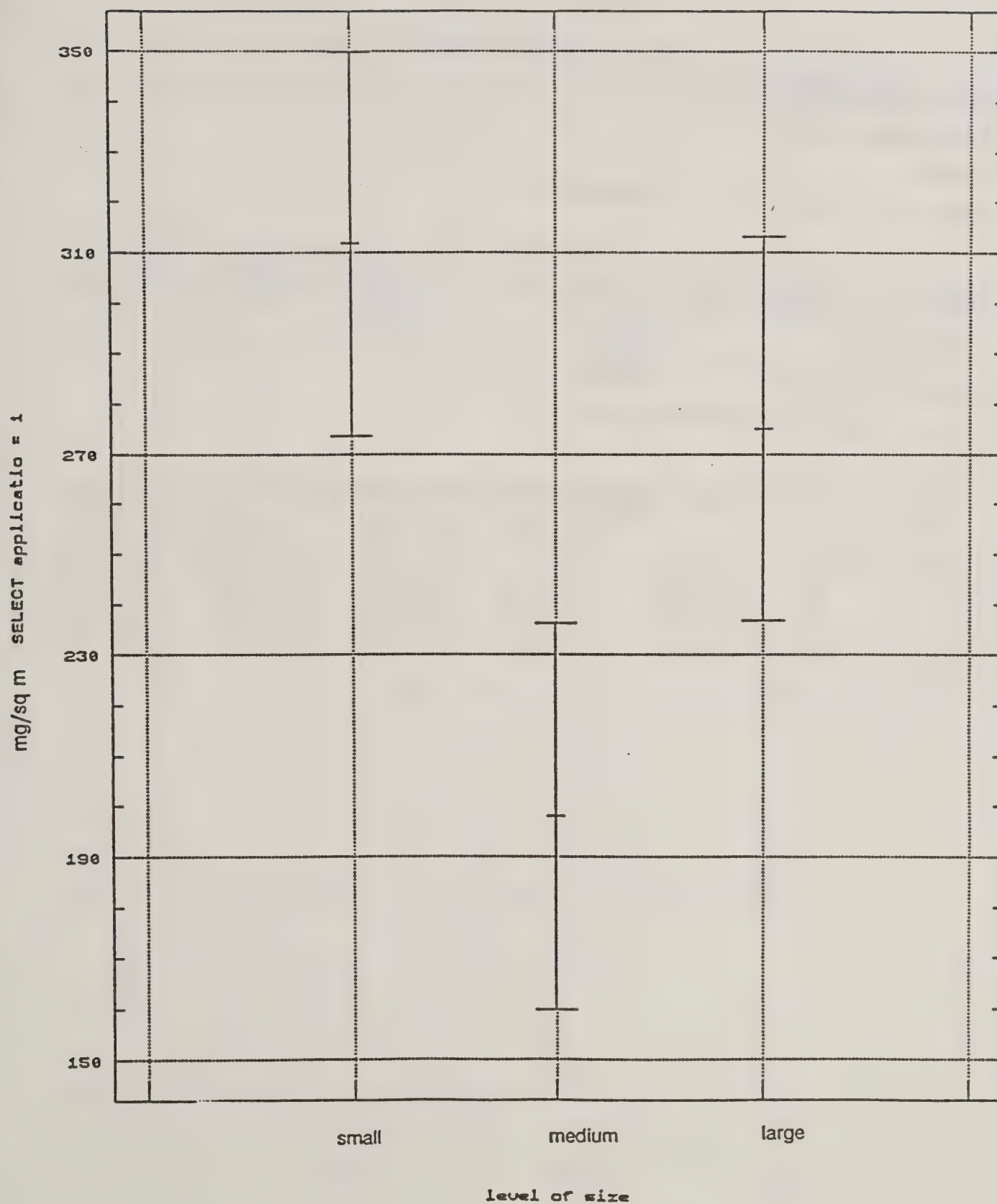
142 missing value(s) have been excluded.

Table of means for mgm2 SELECT applicatio = 1 by size

Level	Count	Average	Std. Error (internal)	Std. Error (pooled s)	95 Percent Confidence intervals for mean	
1	24	311.79125	24.328153	19.125579	273.62814	349.95436
2	24	198.05083	9.992531	19.125579	159.88772	236.21394
3	24	274.97375	20.140843	19.125579	236.81064	313.13686
Total	72	261.60528	11.042158	11.042158	239.57180	283.63876

95 Percent Confidence

Intervals for Factor Means



One-Way Analysis of Variance

Data: mgm2 SELECT applicatio = 2

Level codes: size

Labels:

Range test: Conf. Int. Confidence level: 95

Analysis of variance

Source of variation	Sum of Squares	d.f.	Mean square	F-ratio	Sig. level
Between groups	1080438.5	2	540219.27	9.616	.0002
Within groups	3764130.6	67	56181.05		
Total (corrected)	4844569.2	69			

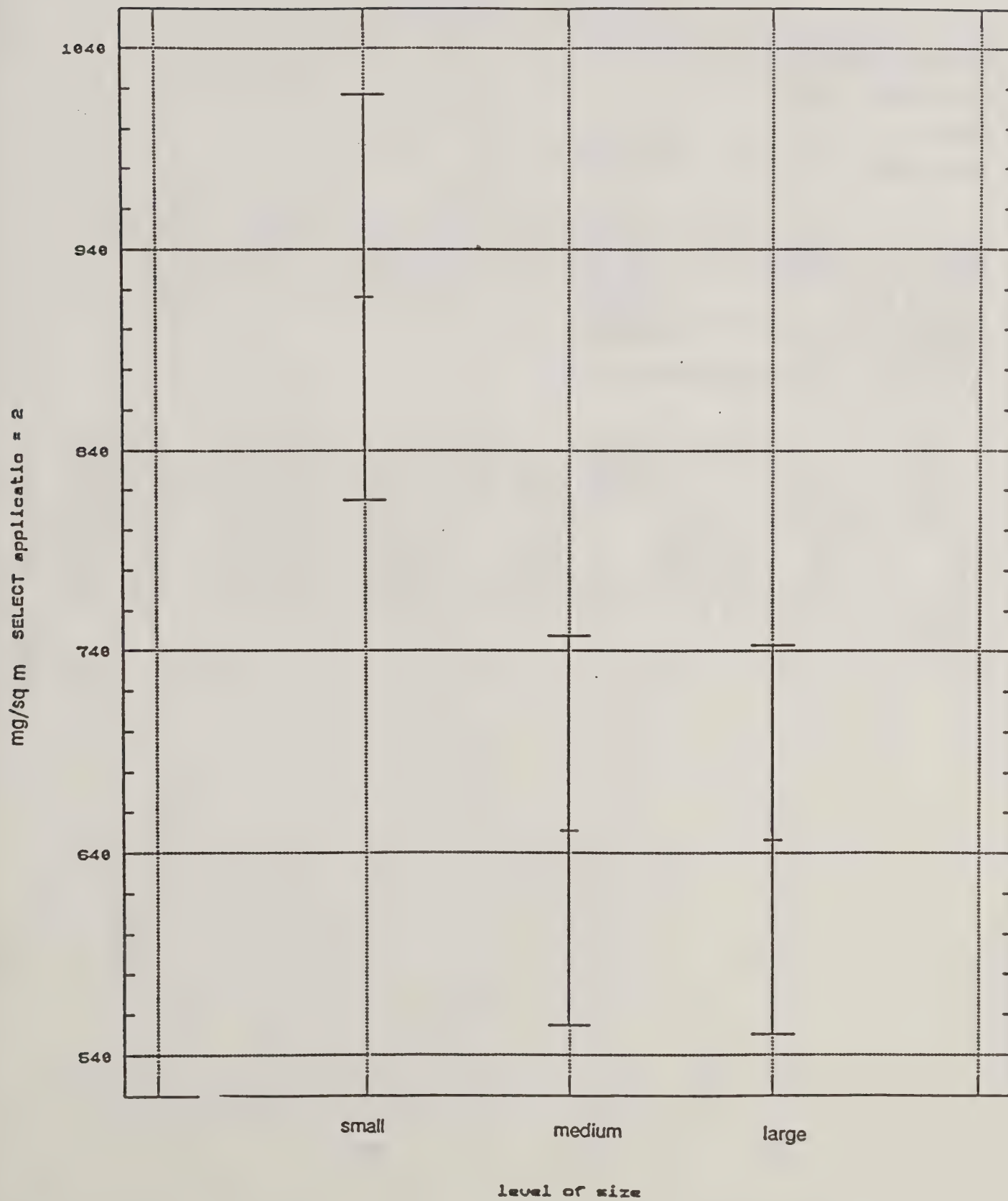
144 missing value(s) have been excluded.

Table of means for mgm2 SELECT applicatio = 2 by size

Level	Count	Average	Stnd. Error (internal)	Stnd. Error (pooled s)	95 Percent Confidence intervals for mean	
1.	22	916.26636	66.786638	50.533991	815.37727	1017.1555
2.	24	650.95625	39.283281	48.382613	554.36230	747.5502
3.	24	646.40000	39.277145	48.382613	549.80605	742.9940
Total	70	732.77729	28.329957	28.329957	676.21766	789.3369

95 Percent Confidence

Intervals for Factor Means



One-Way Analysis of Variance

Data: mgm2 SELECT applicatio = 3

Level codes: size

Labels:

Range test: Conf. Int. Confidence level: 95

Analysis of variance

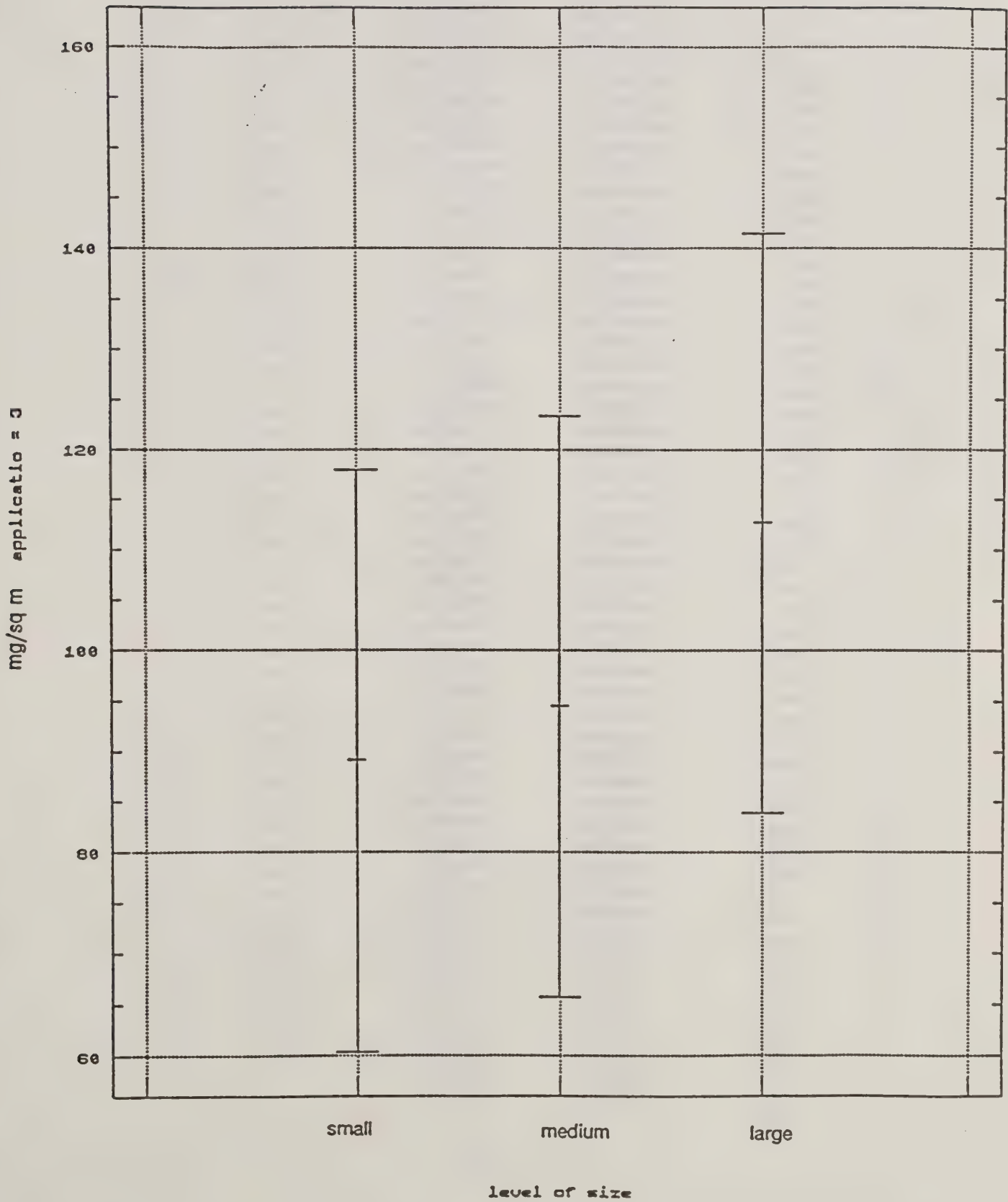
Source of variation	Sum of Squares	d.f.	Mean square	F-ratio	Sig. level
Between groups	7299.69	2	3649.8463	.731	.4851
Within groups	344516.05	69	4992.9862		
Total (corrected)	351815.74	71			

142 missing value(s) have been excluded.

Table of means for mgm2 SELECT applicatio = 3 by size

Level	Count	Average	Std. Error (internal)	Std. Error (pooled s)	95 Percent Confidence intervals for mean	
1.	24	89.17583	11.033627	14.423630	60.394974	117.95669
2.	24	94.56333	15.433497	14.423630	65.782474	123.34419
3.	24	112.71333	16.253908	14.423630	83.932474	141.49419
Total	72	98.81750	8.327486	8.327486	82.200863	115.43414

95 Percent Confidence
Intervals for Factor Means



Trial	ID	MMD	mg/m ²
1	AL1	271.27	226.14
1	AL2	238.63	162.20
1	AL3	276.16	416.79
1	AM1	256.90	218.41
1	AM2	228.96	115.35
1	AM3	249.21	316.29
1	AS1	249.26	468.15
1	AS2	317.69	545.17
1	AS3	268.00	160.60
1	BL1	234.37	282.08
1	BL2	200.82	217.98
1	BL3	262.25	279.71
1	BM1	214.81	95.49
1	BM2	220.84	229.62
1	BM3	215.47	243.10
1	BS1	263.56	321.27
1	BS2	247.53	492.87
1	BS3	244.58	268.03
1	CL1	218.62	237.49
1	CL2	205.51	287.20
1	CL3	272.14	277.03
1	CM1	239.04	151.42
1	CM2	221.75	187.53
1	CM3	212.82	217.56
1	CS1	262.57	353.14
1	CS2	251.29	451.10
1	CS3	255.87	219.84
1	DL1	346.77	399.07
1	DL2	211.95	158.70
1	DL3	245.97	440.48
1	DM1	209.02	168.83
1	DM2	204.80	208.51
1	DM3	205.02	172.77
1	DS1	312.15	318.27
1	DS2	298.99	274.37
1	DS3	253.28	256.36
1	EL1	215.66	242.48
1	EL2	274.73	165.84
1	EL3	208.43	487.69
1	EM1	225.93	155.51
1	EM2	208.26	182.15
1	EM3	273.77	175.08
1	ES1	241.08	229.92
1	ES2	246.15	238.25
1	ES3	249.05	308.52
1	FL1	208.41	276.59
1	FL2	221.45	133.48
1	FL3	202.40	428.66
1	FM1	225.41	171.33
1	FM2	217.64	172.78
1	FM3	215.64	182.85

Trial	ID	MMD	mg/m ²
1	FS1	307.60	388.06
1	FS2	295.66	240.85
1	FS3	316.52	134.35
1	GL1	212.47	245.78
1	GL2	212.30	172.24
1	GL3	257.36	307.60
1	GM1	205.83	201.87
1	GM2	305.71	213.09
1	GM3	229.85	231.81
1	GS1	313.25	529.61
1	GS2	311.23	245.76
1	GS3	245.20	316.80
1	HL1	276.41	325.64
1	HL2	211.79	254.53
1	HL3	219.64	173.97
1	HM1	275.53	280.51
1	HM2	232.25	258.85
1	HM3	274.23	202.51
1	HS1	313.43	268.05
1	HS2	241.81	356.08
1	HS3	201.30	97.57
2	AL1	309.43	573.97
2	AL2	299.58	470.70
2	AL3	346.23	427.49
2	AL4	215.73	278.26
2	AM1	303.05	532.00
2	AM2	298.15	486.47
2	AM3	277.25	322.23
2	AM4	288.55	402.37
2	AS1	347.75	1225.95
2	AS2	392.51	831.67
2	AS3	293.39	907.70
2	AS4	294.76	437.05
2	BL1	306.61	561.41
2	BL2	317.19	479.26
2	BL3	256.22	365.51
2	BL4	278.58	438.04
2	BM1	305.76	559.33
2	BM2	255.74	432.64
2	BM3	282.75	585.08
2	BM4	302.60	346.02
2	BS1	386.70	1119.41
2	BS2	302.56	1017.63
2	BS3	243.10	1001.62
2	BS4	268.29	367.04
2	CL1	338.63	761.22
2	CL2	348.59	592.89
2	CL3	317.26	553.11
2	CL4	284.18	767.58

Trial	ID	MMD	mg/m ²
2	CM1	316.79	487.46
2	CM2	307.44	615.58
2	CM3	332.89	771.02
2	CM4	359.71	848.06
2	CS1	299.65	865.94
2	CS2	353.91	968.61
2	CS3	345.63	454.79
2	CS4	356.20	690.22
2	DL1	246.93	633.27
2	DL2	315.89	631.87
2	DL3	303.25	805.03
2	DL4	355.44	1061.83
2	DM1	297.92	652.91
2	DM2	293.32	685.57
2	DM3	257.31	585.44
2	DM4	305.59	976.23
2	DS1	285.01	1560.86
2	DS2		
2	DS3	299.81	668.25
2	DS4	309.07	884.95
2	EL1	244.03	578.45
2	EL2	311.92	656.18
2	EL3	354.43	925.46
2	EL4	304.53	853.06
2	EM1	356.64	955.99
2	EM2	259.20	656.44
2	EM3	317.41	658.51
2	EM4	285.87	1005.30
2	ES1	308.87	1075.13
2	ES2		
2	ES3	281.80	882.12
2	ES4	305.62	665.46
2	FL1	310.91	842.91
2	FL2	308.10	910.57
2	FL3	311.89	642.12
2	FL4	240.87	703.41
2	FM1	244.96	715.83
2	FM2	251.61	876.33
2	FM3	256.42	671.17
2	FM4	315.02	794.97
2	FS1	357.47	1333.94
2	FS2	340.79	1459.04
2	FS3	307.93	700.61
2	FS4	335.44	1039.87
3	AL1	198.90	5.55
3	AL2	165.93	33.72
3	AL3	257.94	205.18
3	AL4	225.23	82.79
3	AM1	272.81	40.37
3	AM2	194.17	9.75
3	AM3	545.97	99.45

Trial	ID	MMD	mg/m ²
3	AM4	203.95	69.71
3	AS1	271.63	39.86
3	AS2	516.38	110.62
3	AS3	298.47	88.70
3	AS4	634.23	198.40
3	BL1	179.02	87.25
3	BL2	549.62	113.46
3	BL3	162.45	10.75
3	BL4	185.84	14.74
3	BM1	509.11	177.02
3	BM2	169.98	13.24
3	BM3	161.38	37.49
3	BM4	434.25	61.75
3	BS1	582.29	105.79
3	BS2	192.92	4.70
3	BS3	447.86	140.23
3	BS4	223.82	6.19
3	CL1	558.46	147.32
3	CL2	239.98	10.39
3	CL3	466.13	123.75
3	CL4	464.15	114.37
3	CM1	273.29	14.26
3	CM2	225.80	43.96
3	CM3	495.73	237.62
3	CM4	260.00	8.57
3	CS1	218.05	31.21
3	CS2	233.89	34.76
3	CS3	470.92	73.21
3	CS4	502.95	139.57
3	DL1	510.13	183.24
3	DL2	545.18	96.42
3	DL3	675.23	246.29
3	DL4	455.72	227.66
3	DM1	184.72	7.05
3	DM2	468.15	66.67
3	DM3	505.26	76.82
3	DM4	434.09	122.90
3	DS1	421.14	114.36
3	DS2	470.77	72.87
3	DS3	554.45	131.94
3	DS4	438.28	69.00
3	EL1	468.77	68.14
3	EL2	162.99	32.89
3	EL3	508.28	85.98
3	EL4	504.58	224.25
3	EM1	438.73	69.82
3	EM2	485.19	168.97
3	EM3	378.85	119.90
3	EM4	369.25	214.16

Trial	ID	MMD	mg/m ²
3	ES1	437.59	67.77
3	ES2	542.28	170.66
3	ES3	441.91	126.14
3	ES4	460.21	47.86
3	FL1	437.34	67.31
3	FL2	471.40	195.98
3	FL3	209.44	248.09
3	FL4	506.18	79.60
3	FM1	476.80	87.13
3	FM2	517.65	228.93
3	FM3	469.87	223.93
3	FM4	503.04	70.05
3	FS1	168.24	12.75
3	FS2	550.70	117.56
3	FS3	395.41	166.71
3	FS4	385.97	69.36



Figure E-1. Sampling array for testing collection efficiency of different size cards.

APPENDIX F

STATISTICAL COMPARISONS OF 1991 CANOPY PENETRATION HAND AND MACHINE COUNTED CARD SAMPLES

HAND COUNTED CARD SAMPLES
TEST FOR DIFFERENCE BETWEEN SAMPLING LINES AT ABOVE-CANOPY LEVEL

One-Way Analysis of Variance

Data: high

Level codes: line

Labels:

Range test: Conf. Int. Confidence level: 95

Analysis of variance

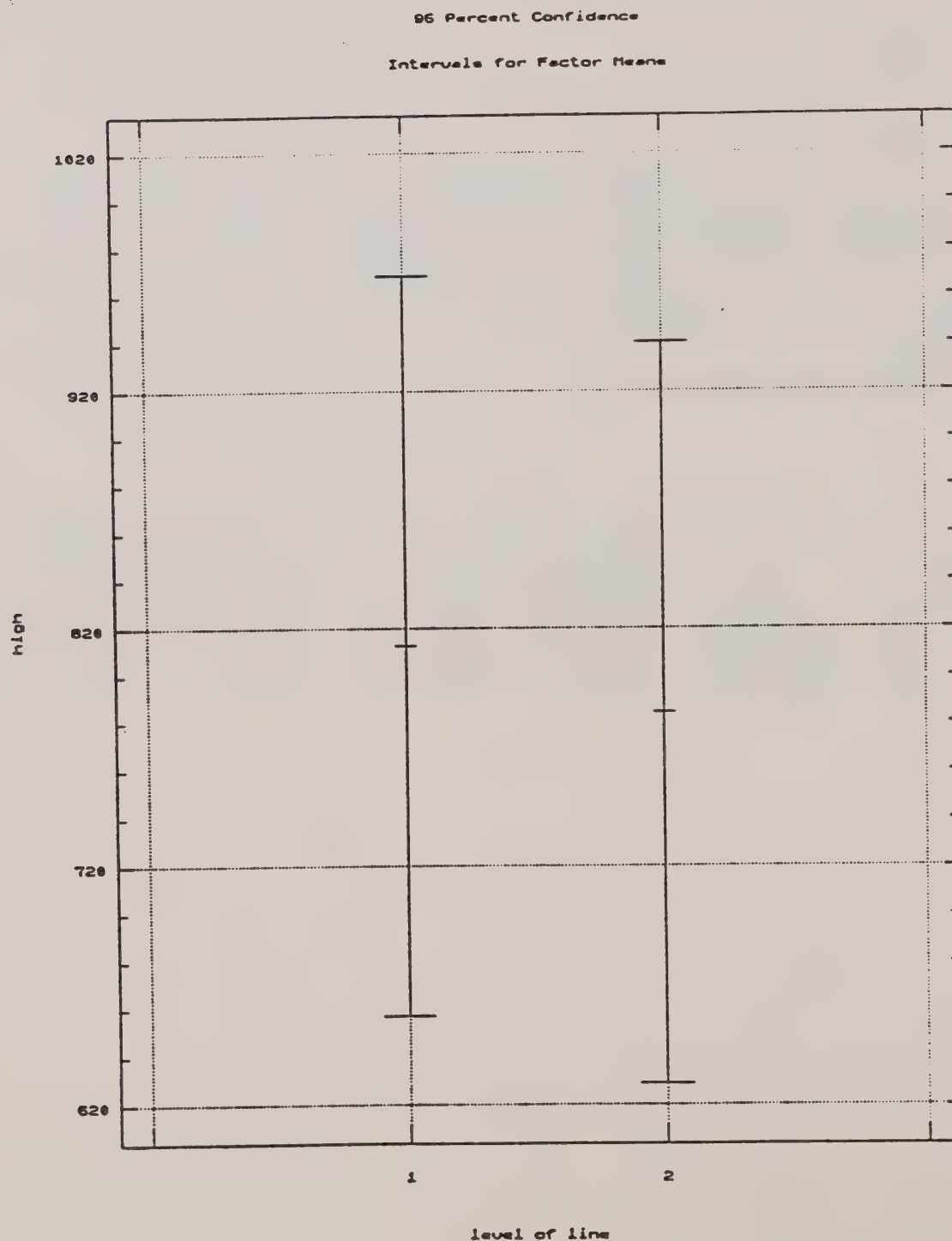
Source of variation	Sum of Squares	d.f.	Mean square	F-ratio	Sig. level
Between groups	25021	1	25020.69	.065	.8016
Within groups	46827236	122	383829.80		
Total (corrected)	46852257	123			

2 missing value(s) have been excluded.

Table of means for high by line

Level	Count	Average	Std. Error (internal)	Std. Error (pooled s)	95 Percent Confidence intervals for mean	
1	62	812.88145	81.723985	78.681658	657.08846	968.67444
2	62	784.47161	75.516865	78.681658	628.67862	940.26460
Total	124	798.67653	55.636334	55.636334	688.51425	908.83881

HAND COUNTED CARD SAMPLES
TEST FOR DIFFERENCE BETWEEN SAMPLING LINES AT ABOVE-CANOPY LEVEL



HAND COUNTED CARD SAMPLES
TEST FOR DIFFERENCE BETWEEN SAMPLING LINES AT MID-CANOPY LEVEL

One-Way Analysis of Variance

Data: mid

Level codes: line

Labels:

Range test: Conf. Int. Confidence level: 95

Analysis of variance

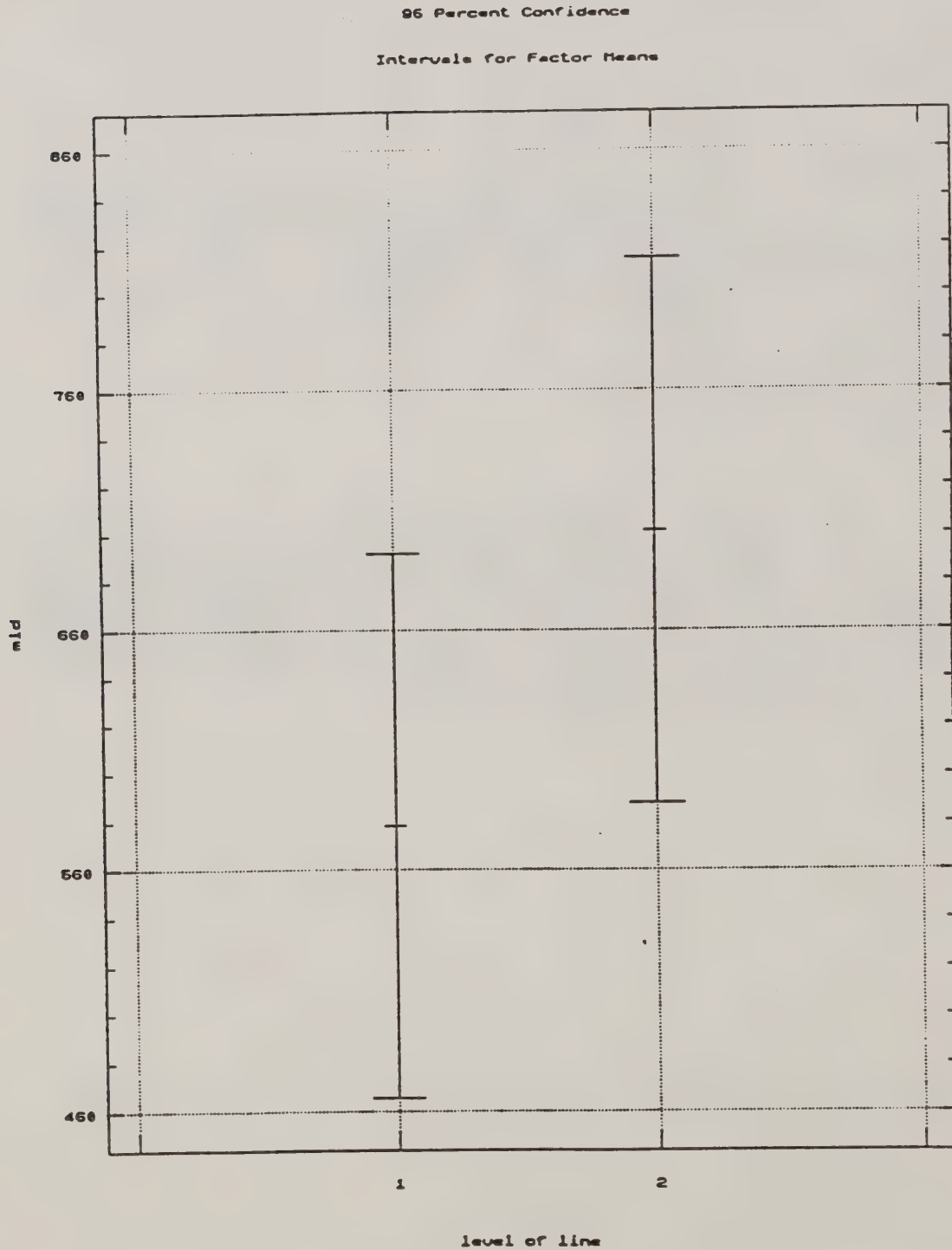
Source of variation	Sum of Squares	d.f.	Mean square	F-ratio	Sig. level
Between groups	316685	1	316685.24	2.325	.1312
Within groups	11168912	82	136206.25		
Total (corrected)	11485598	83			

42 missing value(s) have been excluded.

Table of means for mid by line

Level	Count	Average	Std. Error (internal)	Std. Error (pooled s)	95 Percent Confidence intervals for mean	
1	42	578.58286	46.100235	56.947396	465.27085	691.89487
2	42	701.38452	66.036203	56.947396	588.07251	814.69653
Total	84	639.98369	40.267890	40.267890	559.86000	720.10738

HAND COUNTED CARD SAMPLES
TEST FOR DIFFERENCE BETWEEN SAMPLING LINES AT MID-CANOPY LEVEL



HAND COUNTED CARD SAMPLES
TEST FOR DIFFERENCE BETWEEN SAMPLING LINES AT GROUND LEVEL

One-Way Analysis of Variance

Data: ground

Level codes: line

Labels:

Range test: Conf. Int. Confidence level: 95

Analysis of variance

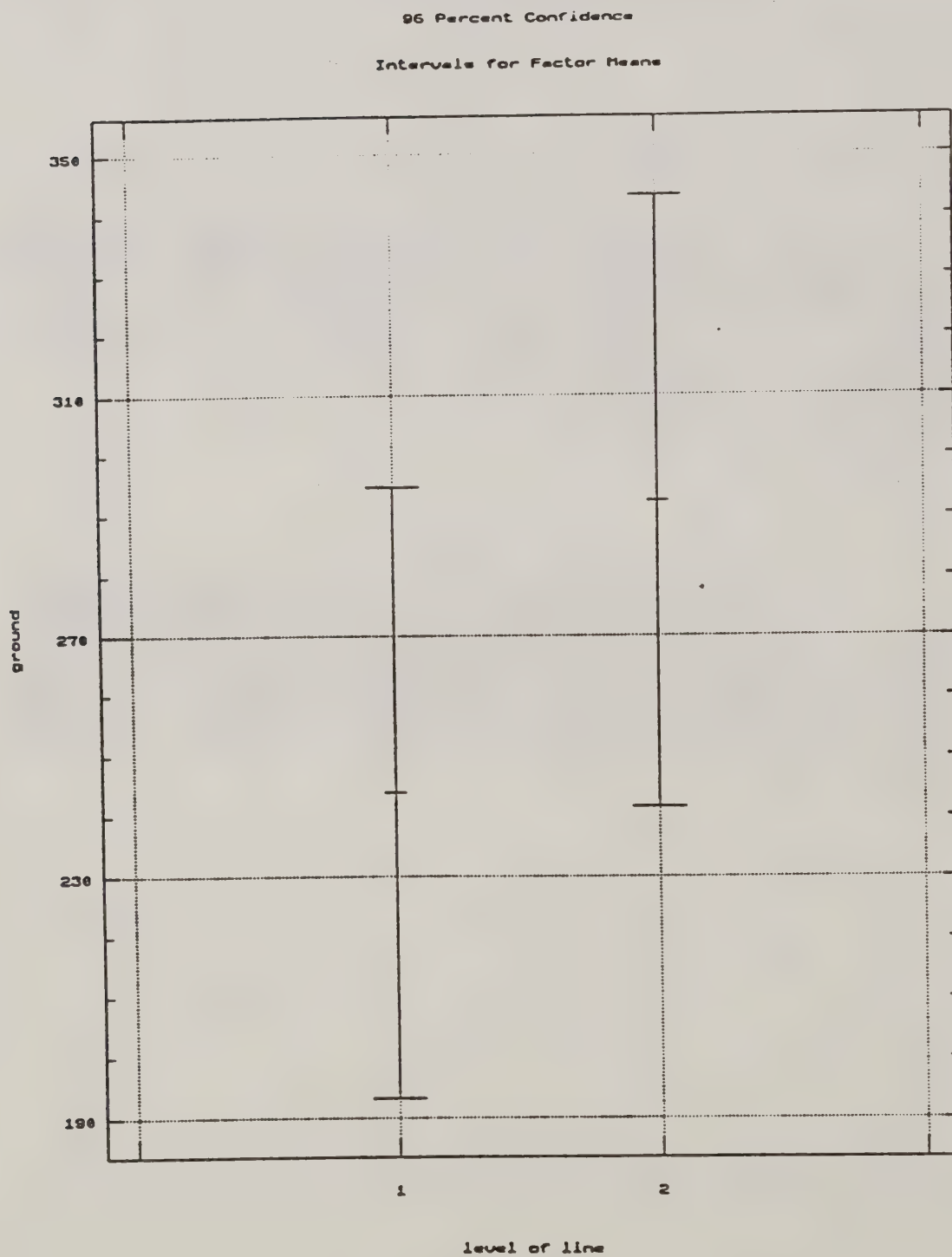
Source of variation	Sum of Squares	d.f.	Mean square	F-ratio	Sig. level
Between groups	74058.5	1	74058.535	1.786	.1839
Within groups	5142832.1	124	41474.453		
Total (corrected)	5216890.6	125			

0 missing value(s) have been excluded.

Table of means for ground by line

Level	Count	Average	Std. Error (internal)	Std. Error (pooled s)	95 Percent Confidence intervals for mean	
1	63	243.91286	22.334309	25.657838	193.11747	294.70825
2	63	292.40063	28.597691	25.657838	241.60525	343.19602
Total	126	268.15675	18.142831	18.142831	232.23898	304.07451

HAND COUNTED CARD SAMPLES
TEST FOR DIFFERENCE BETWEEN SAMPLING LINES AT GROUND LEVEL



HAND COUNTED CARD SAMPLES
TEST FOR DIFFERENCE BETWEEN TRIALS AT ABOVE-CANOPY LEVEL

One-Way Analysis of Variance

Data: high

Level codes: trial

Labels:

Range test: Conf. Int. Confidence level: 95

Analysis of variance

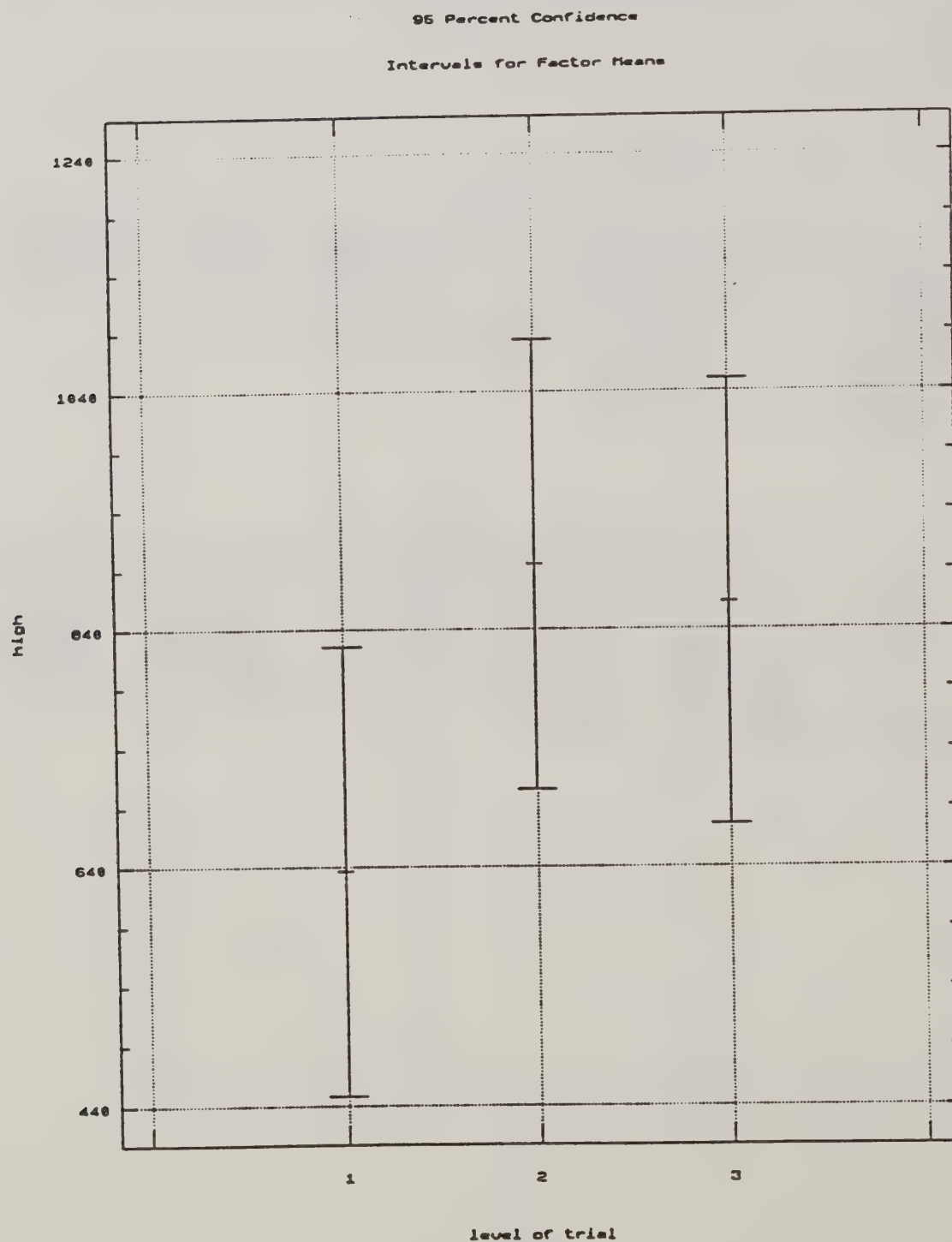
Source of variation	Sum of Squares	d.f.	Mean square	F-ratio	Sig. level
Between groups	1629121	2	814560.36	2.179	.1175
Within groups	45223136	121	373744.93		
Total (corrected)	46852257	123			

2 missing value(s) have been excluded.

Table of means for high by trial

Level	Count	Average	Std. Error (internal)	Std. Error (pooled s)	95 Percent Confidence intervals for mean	
1	41	636.64000	40.33073	95.476332	447.57719	825.7028
2	41	894.76854	90.95448	95.476332	705.70573	1083.8313
3	42	863.05095	129.74626	94.332861	676.25245	1049.8495
Total	124	798.67653	54.90056	54.900565	689.96210	907.3910

HAND COUNTED CARD SAMPLES
TEST FOR DIFFERENCE BETWEEN TRIALS AT ABOVE-CANOPY LEVEL



HAND COUNTED CARD SAMPLES
TEST FOR DIFFERENCE BETWEEN TRIALS AT MID-CANOPY LEVEL

One-Way Analysis of Variance

Data: mid

Level codes: trial

Labels:

Range test: Conf. Int. Confidence level: 95

Analysis of variance

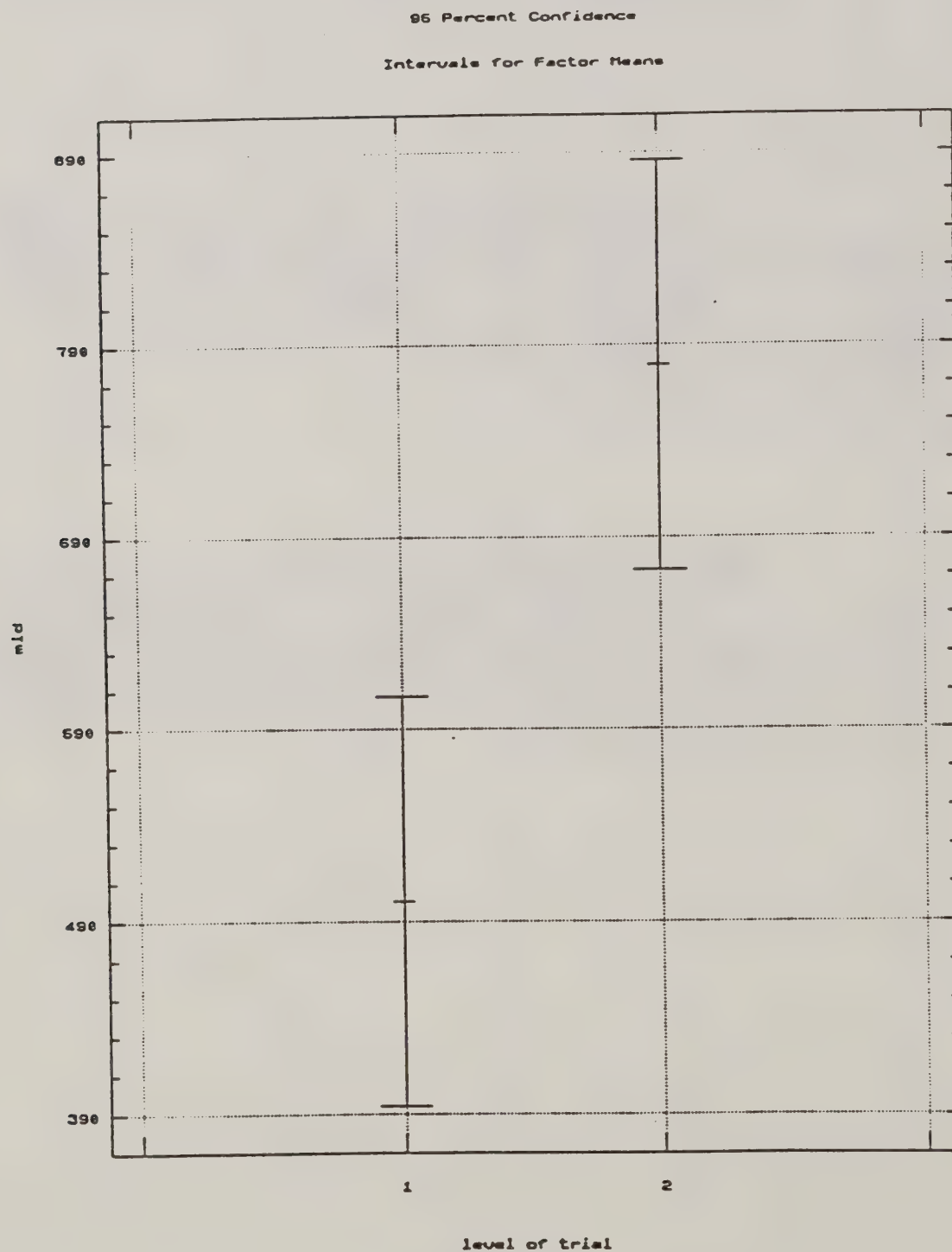
Source of variation	Sum of Squares	d.f.	Mean square	F-ratio	Sig. level
Between groups	1633168.7	1	1633168.7	13.593	.0004
Within groups	9852428.9	82	120151.6		
Total (corrected)	11485598	83			

42 missing value(s) have been excluded.

Table of means for mid by trial

Level	Count	Average	Std. Error (internal)	Std. Error (pooled s)	95 Percent Confidence intervals for mean	
1	42	500.54738	43.267458	53.485995	394.12275	606.97201
2	42	779.42000	62.043778	53.485995	672.99537	885.84463
Total	84	639.98369	37.820310	37.820310	564.73011	715.23727

HAND COUNTED CARD SAMPLES
TEST FOR DIFFERENCE BETWEEN TRIALS AT MID-CANOPY LEVEL



HAND COUNTED CARD SAMPLES TEST FOR DIFFERENCE BETWEEN TRIALS AT GROUND LEVEL

One-Way Analysis of Variance

Data: ground

Level codes: trial

Labels:

Range test: Conf. Int. Confidence level: 95

Analysis of variance

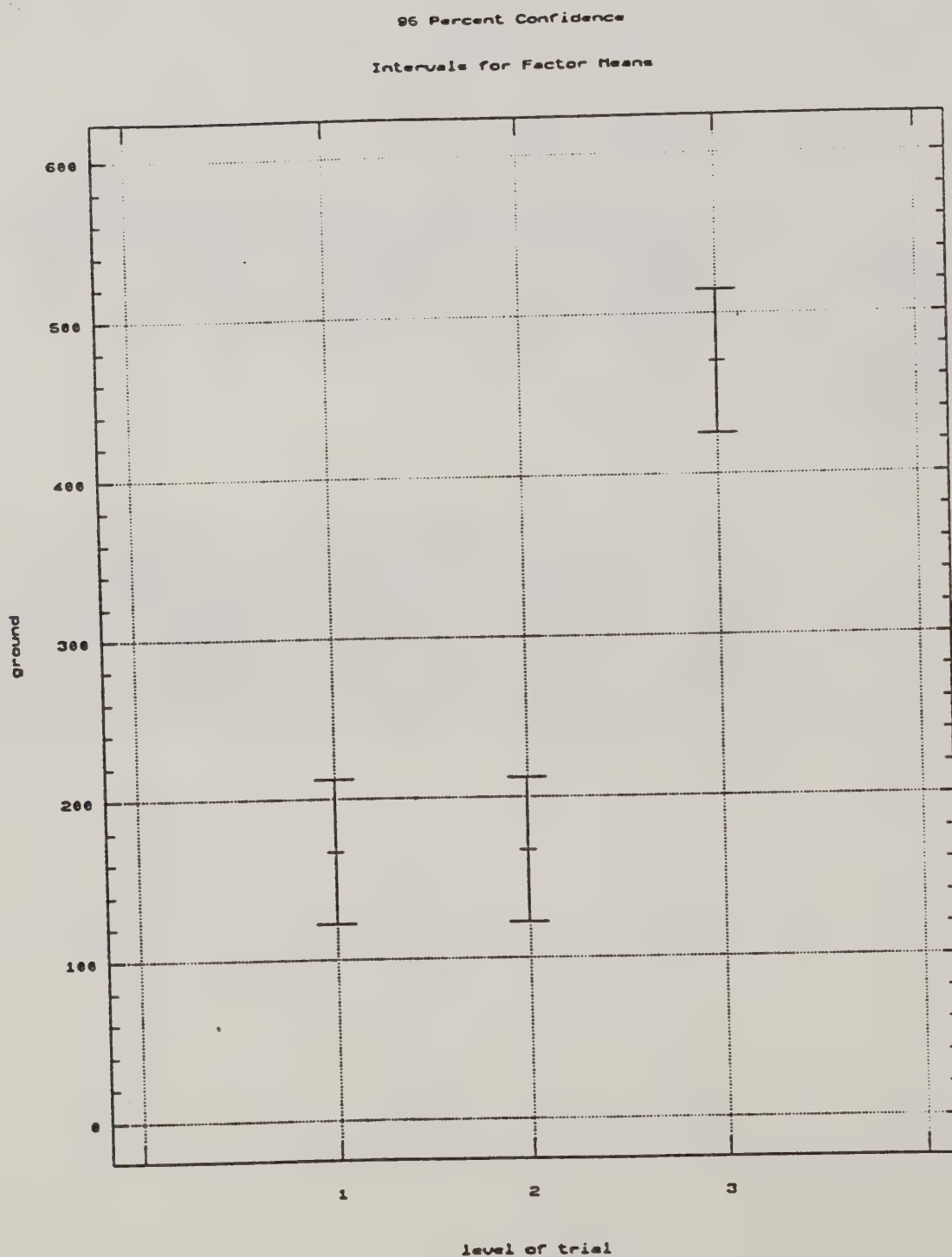
Source of variation	Sum of Squares	d.f.	Mean square	F-ratio	Sig. level
Between groups	2564418.2	2	1282209.1	59.458	.0000
Within groups	2652472.5	123	21564.8		
Total (corrected)	5216890.6	125			

0 missing value(s) have been excluded.

Table of means for ground by trial

Level	Count	Average	Std. Error (internal)	Std. Error (pooled s)	95 Percent Confidence intervals for mean	
1	42	167.24048	14.662999	22.659392	122.37758	212.10337
2	42	167.31810	19.989660	22.659392	122.45520	212.18099
3	42	469.91167	30.426206	22.659392	425.04877	514.77456
Total	126	268.15675	13.082406	13.082406	242.25514	294.05835

HAND COUNTED CARD SAMPLES
TEST FOR DIFFERENCE BETWEEN TRIALS AT GROUND LEVEL



MACHINE COUNTED CARD SAMPLES
TEST FOR DIFFERENCE BETWEEN SAMPLING LINES AT ABOVE-CANOPY LEVEL

One-Way Analysis of Variance

Data: high

Level codes: line

Labels:

Range test: Conf. Int. Confidence level: 95

Analysis of variance

Source of variation	Sum of Squares	d.f.	Mean square	F-ratio	Sig. level
Between groups	18.7	1	18.712	.001	.9754
Within groups	2320810.1	122	19023.034		
Total (corrected)	2320828.8	123			

2 missing value(s) have been excluded.

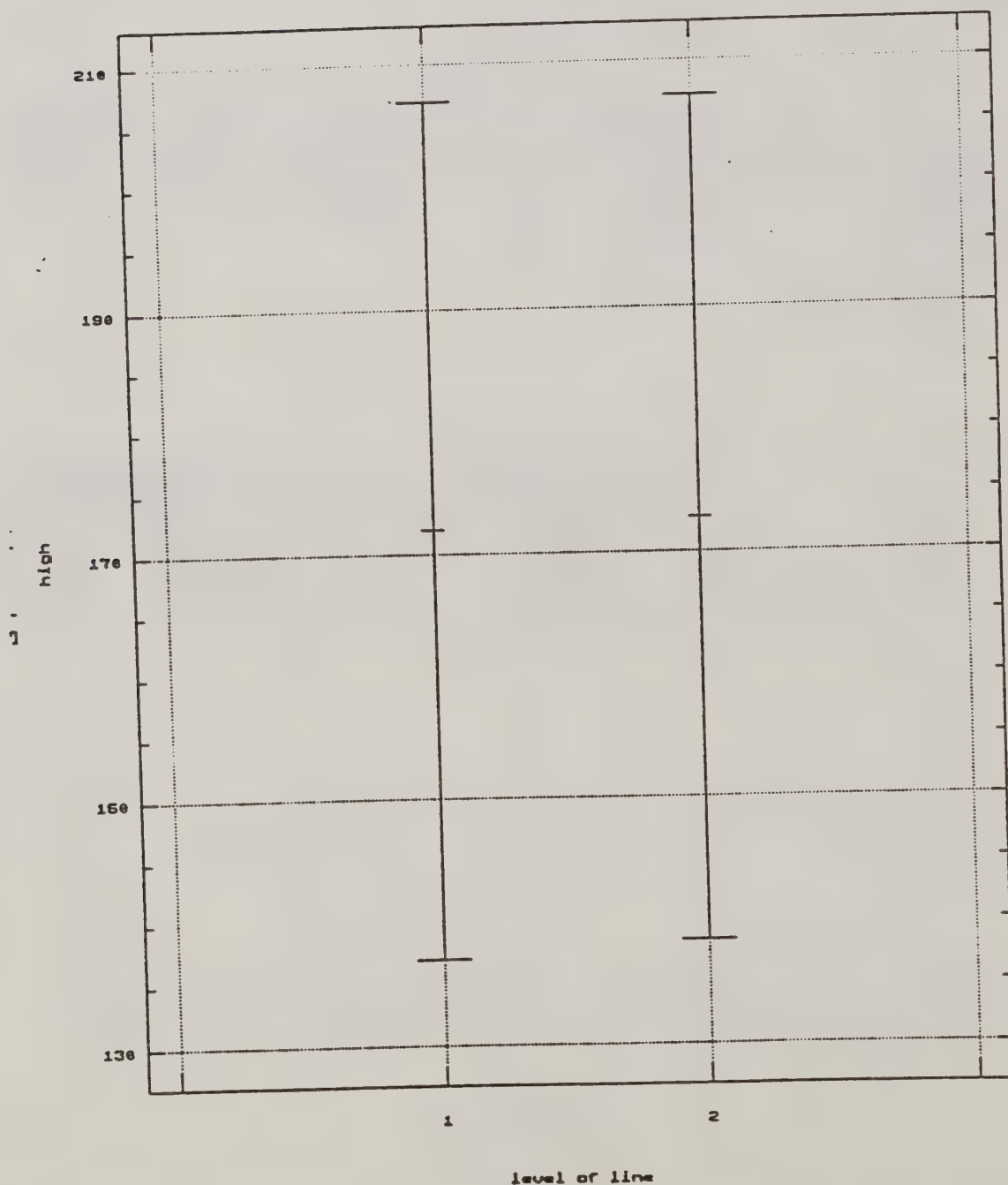
Table of means for high by line

Level	Count	Average	Std. Error (internal)	Std. Error (pooled s)	95 Percent Confidence intervals for mean	
1	61	172.00361	18.275213	17.659360	137.03733	206.96988
2	63	172.78063	16.769504	17.376792	138.37386	207.18741
Total	124	172.39839	12.385942	12.385942	147.87370	196.92307

MACHINE COUNTED CARD SAMPLES
TEST FOR DIFFERENCE BETWEEN SAMPLING LINES AT ABOVE-CANOPY LEVEL

96 Percent Confidence

Intervals for Factor Means



MACHINE COUNTED CARD SAMPLES
TEST FOR DIFFERENCE BETWEEN SAMPLING LINES AT MID-CANOPY LEVEL

One-Way Analysis of Variance

Data: mid

Level codes: line

Labels:

Range test: Conf. Int. Confidence level: 95

Analysis of variance

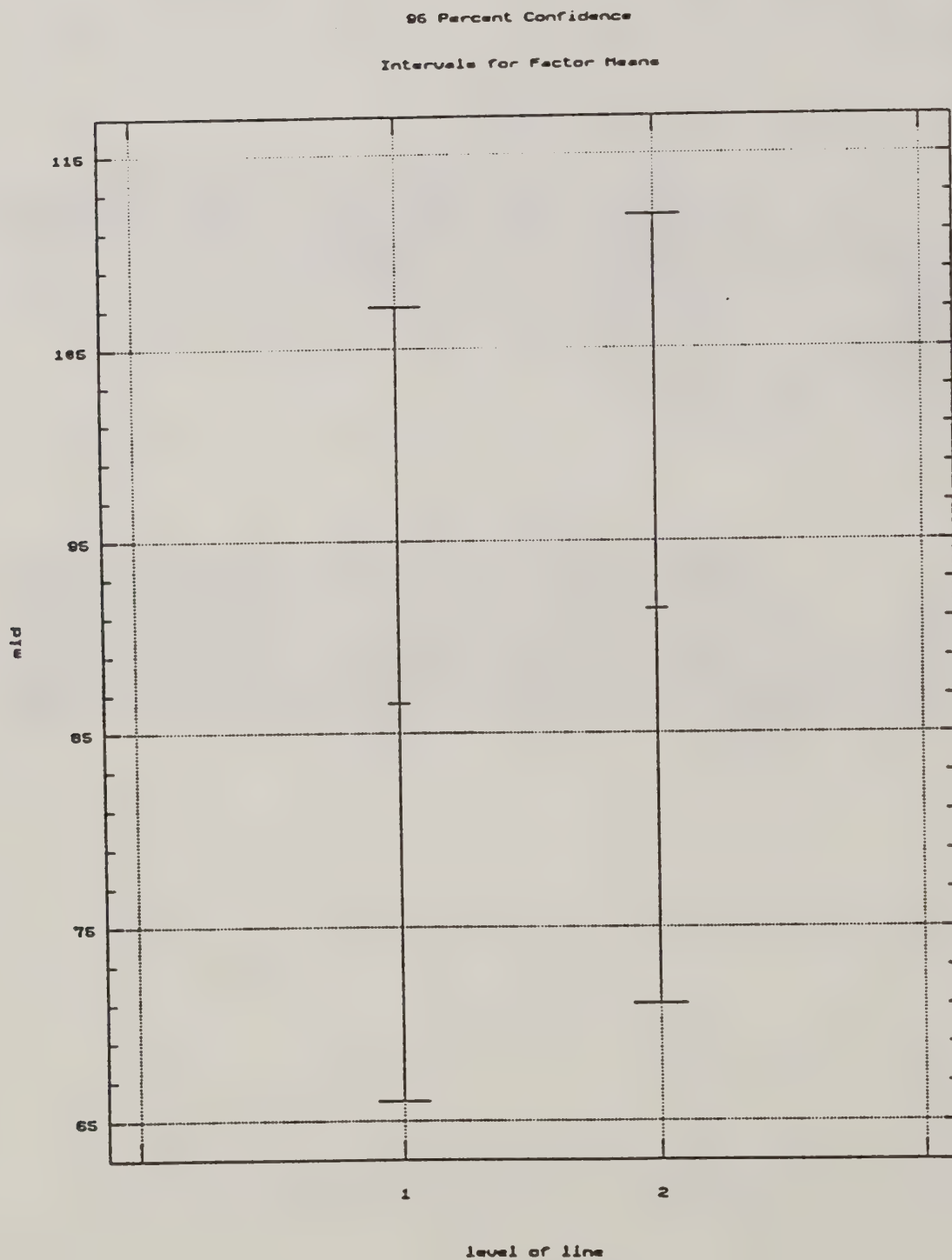
Source of variation	Sum of Squares	d.f.	Mean square	F-ratio	Sig. level
Between groups	732.35	1	732.3531	.111	.7430
Within groups	797252.83	121	6588.8664		
Total (corrected)	797985.19	122			

3 missing value(s) have been excluded.

Table of means for mid by line

Level	Count	Average	Std. Error (internal)	Std. Error (pooled s)	95 Percent Confidence intervals for mean	
1	61	86.567541	12.029135	10.392988	65.987283	107.14780
2	62	91.447903	8.412464	10.308833	71.034290	111.86152
Total	123	89.027561	7.319018	7.319018	74.534398	103.52072

MACHINE COUNTED CARD SAMPLES
TEST FOR DIFFERENCE BETWEEN SAMPLING LINES AT MID-CANOPY LEVEL



MACHINE COUNTED CARD SAMPLES
TEST FOR DIFFERENCE BETWEEN SAMPLING LINES AT GROUND LEVEL

One-Way Analysis of Variance

Data: ground

Level codes: line

Labels:

Range test: Conf. Int. Confidence level: 95

Analysis of variance

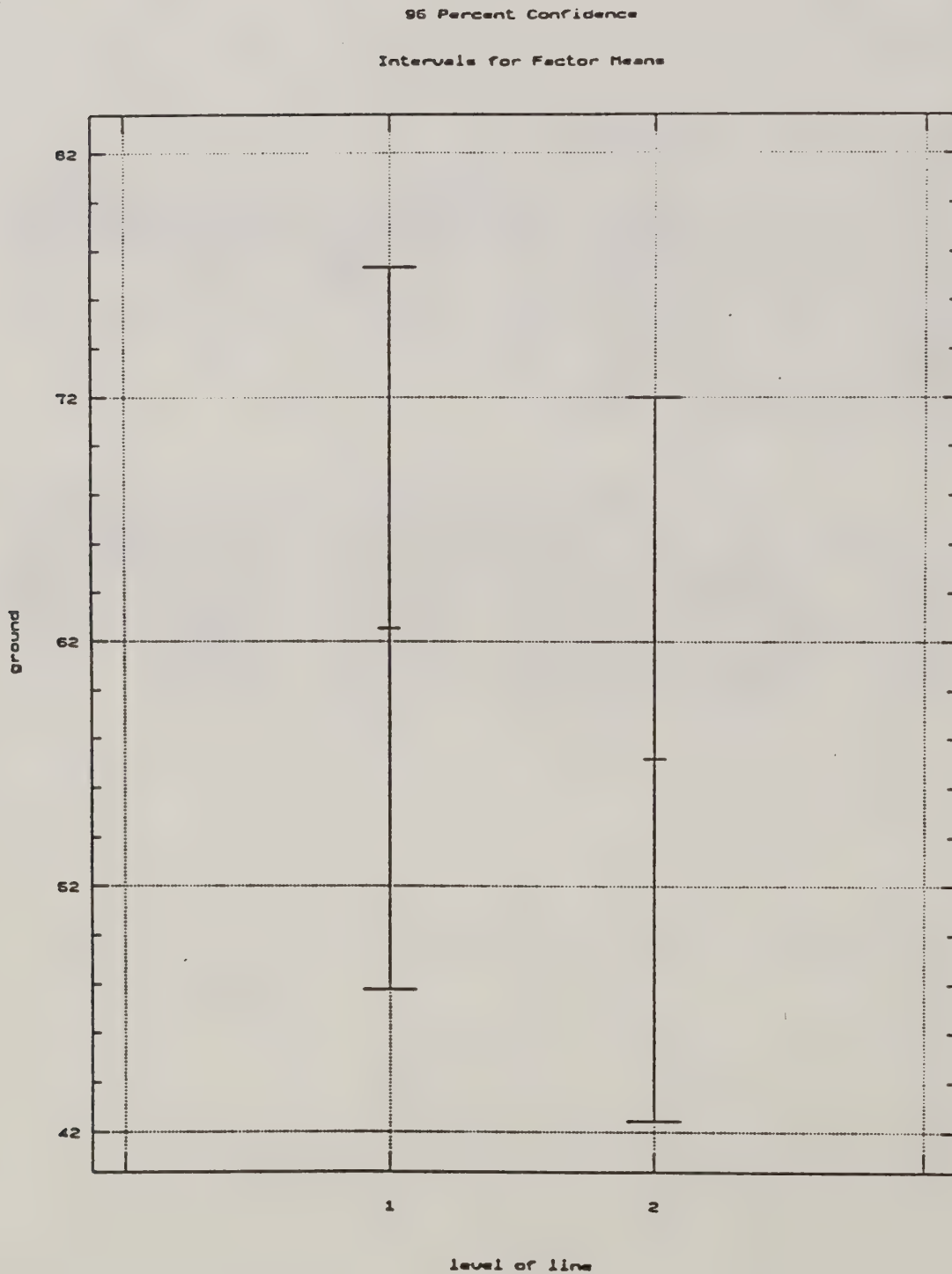
Source of variation	Sum of Squares	d.f.	Mean square	F-ratio	Sig. level
Between groups	877.91	1	877.9065	.254	.6204
Within groups	421364.14	122	3453.8044		
Total (corrected)	422242.05	123			

2 missing value(s) have been excluded.

Table of means for ground by line

Level	Count	Average	Std. Error (internal)	Std. Error (pooled s)	95 Percent Confidence intervals for mean	
1	62	62.545806	8.1654954	7.4636803	47.767406	77.324207
2	62	57.224194	6.6886270	7.4636803	42.445793	72.002594
Total	124	59.885000	5.2776189	5.2776189	49.435093	70.334907

MACHINE COUNTED CARD SAMPLES
TEST FOR DIFFERENCE BETWEEN SAMPLING LINES AT GROUND LEVEL



MACHINE COUNTED CARD SAMPLES
TEST FOR DIFFERENCE BETWEEN TRIALS AT ABOVE-CANOPY LEVEL

One-Way Analysis of Variance

Data: high

Level codes: trial

Labels:

Range test: Conf. Int. Confidence level: 95

Analysis of variance

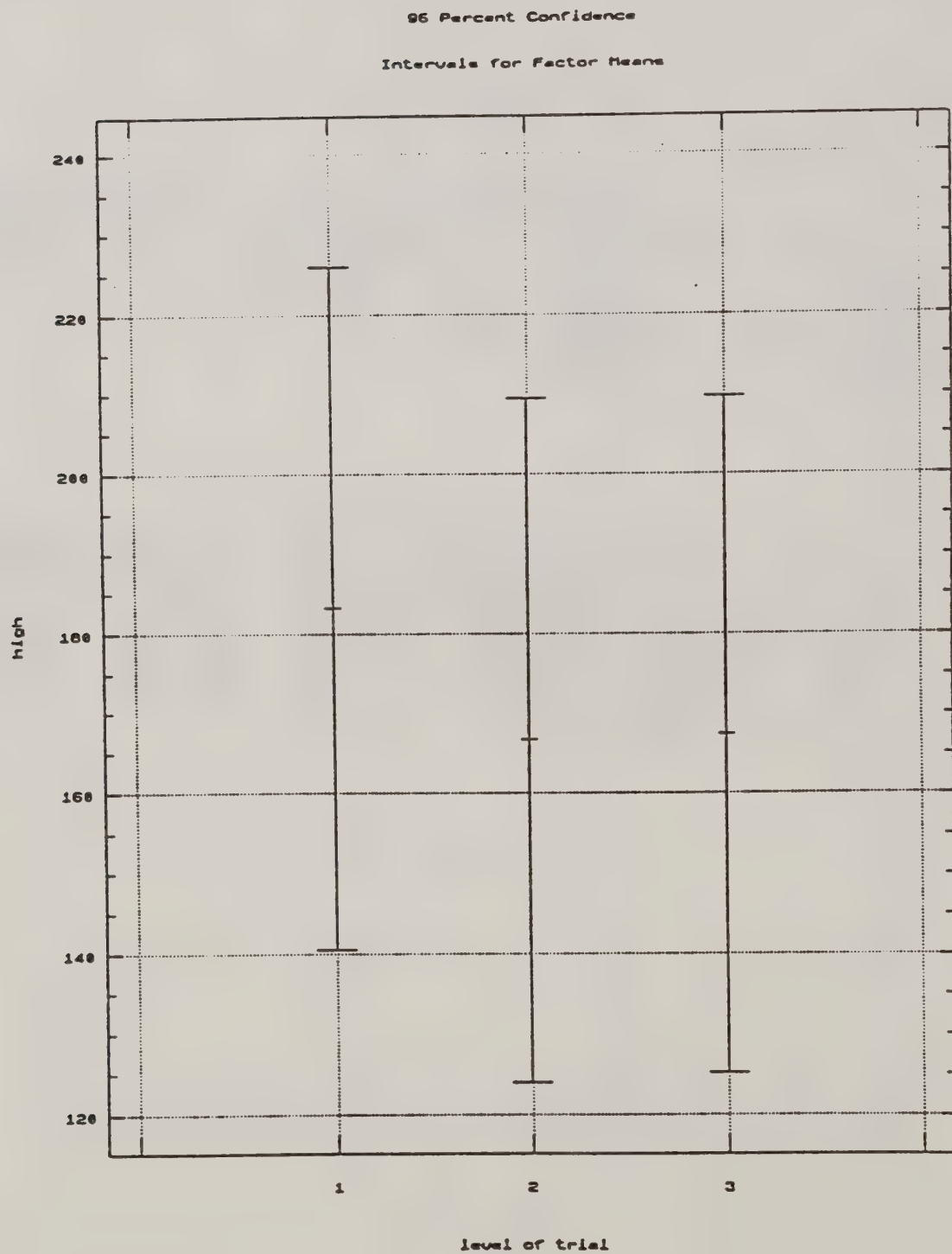
Source of variation	Sum of Squares	d.f.	Mean square	F-ratio	Sig. level
Between groups	7215.0	2	3607.509	.189	.8283
Within groups	2313613.8	121	19120.775		
Total (corrected)	2320828.8	123			

2 missing value(s) have been excluded.

Table of means for high by trial

Level	Count	Average	Std. Error (internal)	Std. Error (pooled s)	95 Percent Confidence intervals for mean	
1	41	183.24390	21.204362	21.595378	140.48060	226.00720
2	41	166.68756	21.113546	21.595378	123.92426	209.45086
3	42	167.38595	22.153864	21.336742	125.13481	209.63710
Total	124	172.39839	12.417721	12.417721	147.80874	196.98803

MACHINE COUNTED CARD SAMPLES
TEST FOR DIFFERENCE BETWEEN TRIALS AT ABOVE-CANOPY LEVEL



MACHINE COUNTED CARD SAMPLES
TEST FOR DIFFERENCE BETWEEN TRIALS AT MID-CANOPY LEVEL

One-Way Analysis of Variance

Data: mid

Level codes: trial

Labels:

Range test: Conf. Int. Confidence level: 95

Analysis of variance

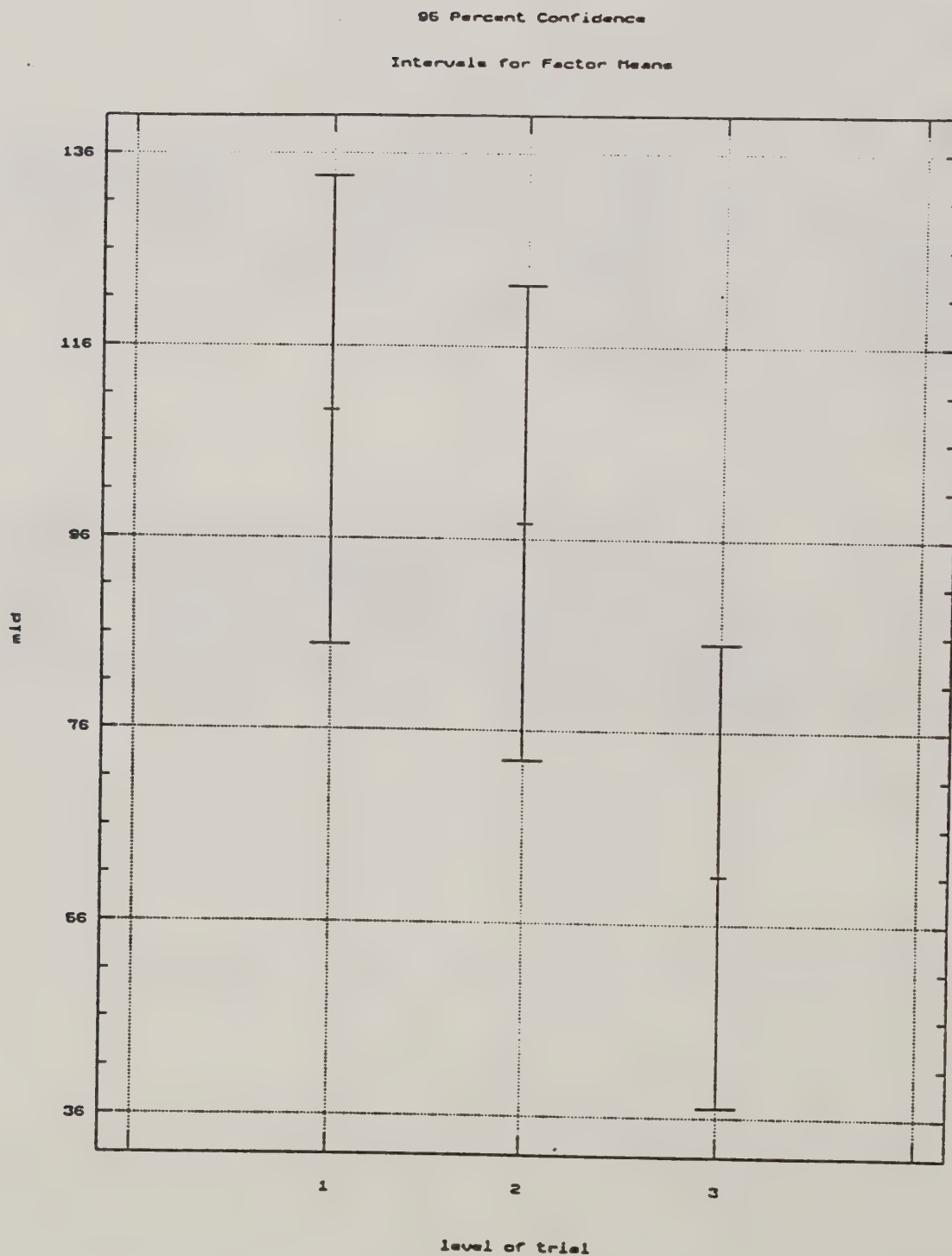
Source of variation	Sum of Squares	d.f.	Mean square	F-ratio	Sig. level
Between groups	52634.16	2	26317.078	4.237	.0167
Within groups	745351.03	120	6211.259		
Total (corrected)	797985.19	122			

3 missing value(s) have been excluded.

Table of means for mid by trial

Level	Count	Average	Std. Error (internal)	Std. Error (pooled s)	95 Percent Confidence intervals for mean	
1	41	109.29098	13.205524	12.308294	84.915965	133.66599
2	40	97.62075	14.755839	12.461198	72.942932	122.29857
3	42	61.06262	8.337117	12.160884	36.979535	85.14570
Total	123	89.02756	7.106197	7.106197	74.954642	103.10048

MACHINE COUNTED CARD SAMPLES
TEST FOR DIFFERENCE BETWEEN TRIALS AT MID-CANOPY LEVEL



MACHINE COUNTED CARD SAMPLES
TEST FOR DIFFERENCE BETWEEN TRIALS AT GROUND LEVEL

One-Way Analysis of Variance

Data: ground

Level codes: trial

Labels:

Range test: Conf. Int. Confidence level: 95

Analysis of variance

Source of variation	Sum of Squares	d.f.	Mean square	F-ratio	Sig. level
Between groups	14044.59	2	7022.2956	2.082	.1292
Within groups	408197.45	121	3373.5327		
Total (corrected)	422242.05	123			

2 missing value(s) have been excluded.

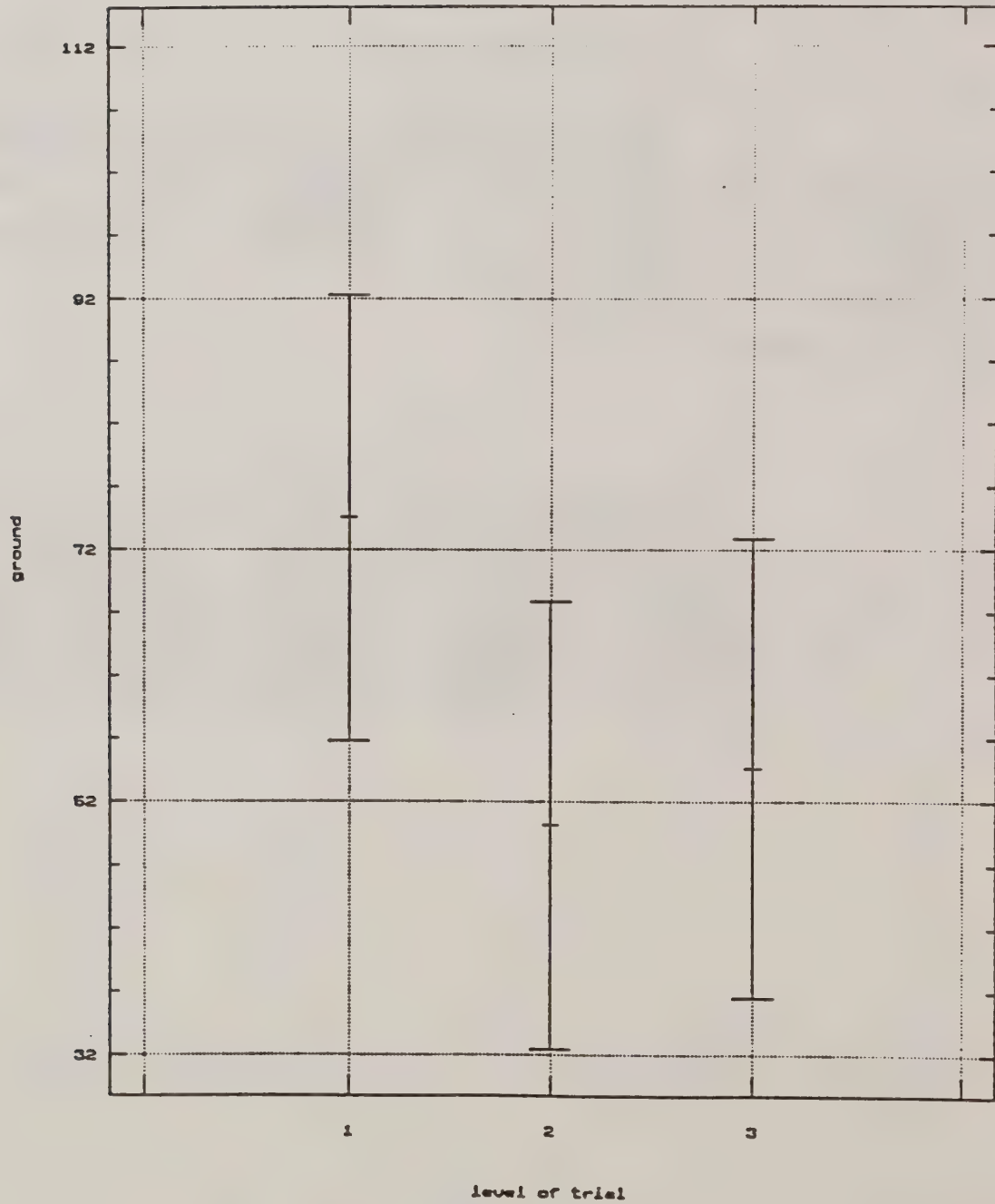
Table of means for ground by trial

Level	Count	Average	Std. Error (internal)	Std. Error (pooled s)	95 Percent Confidence intervals for mean	
1	42	74.532619	10.853078	8.9622657	56.785487	92.279752
2	42	50.179524	6.266104	8.9622657	32.432391	67.926656
3	40	54.695750	9.396930	9.1835896	36.510351	72.881149
Total	124	59.885000	5.215928	5.2159284	49.556387	70.213613

MACHINE COUNTED CARD SAMPLES
TEST FOR DIFFERENCE BETWEEN TRIALS AT GROUND LEVEL

95 Percent Confidence

Intervals for Factor Means

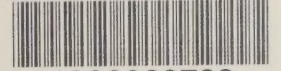


APPENDIX G

REFERENCES

REFERENCES

1. Bjorklund, J. R., Bowman, C. R., and Dodd, G. C., 1988: User Manual for the FSCBG Aircraft Spray and Dispersion Model, Version 2.0. DPG Document No. DPG/TA-88/015, U.S. Army Dugway Proving Ground, Dugway, UT 84022.
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